Exploring coherence of Grade Six students' views of the nature of science (NOS) and their views of the natural world: A South African study

by

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DECLARATION

The thesis *Exploring coherence of Grade Six students' views of the nature of science (NOS) and their views of the natural world: A South African study* contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of my knowledge and belief, this thesis contains no material previously published by any other person except where due acknowledgment has been made.

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ABSTRACT

The aim of this study was to explore the coherence of Grade Six students' views of the nature of science (NOS) and their views of the natural world (a component of worldview). The study therefore comprised three parts that were related to each of these aspects.

In the first part of the study (i.e., NOS), the focus was on the students' views of the nature of scientists' work and the role/purpose of science and, more specifically, on the students' levels of understanding about five key aspects of NOS identified by N.G. Lederman (2007). These five aspects include the tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative/creative aspects of NOS. The second part of the study (i.e., views of the natural world) focussed on the students' definitions of Nature and, in particular, on the students' epistemological, ontological, emotional and status descriptions of Nature, in line with the work of Cobern (1991, 2000b). The focus of the third part of the study (i.e., coherence) was on exploring the coherence within and between these two domains by identifying and examining coherent and incoherent links between the students' views of NOS and of Nature, as well as by determining the overall coherence of the students' views using Thagard's (1989, 1992, 1994, 2006) explanatory coherence theory.

In order to collect rich data concerning the students' views of NOS and of the natural world, a qualitative research design was employed, namely, a multiple case study. Fourteen Grade Six students were purposively selected in order to maximise the diversity of views of the natural world represented by the students, whilst also controlling for a number of other factors (e.g., nationality, language, age, religion, socio-economic status, nature of science teaching at school) that might impact on the students' views of NOS. Evidence of the religious affiliation, and of the science—and NOS—teaching at each school was collected by means of semi-structured interviews with school principals and science teachers, respectively. Introductory questionnaires were then administered to the students in order to record details of their personal background information.

Data concerning the students' NOS views (i.e., Part One) were collected by means of written questionnaires and semi-structured follow-up interviews, and analysed using an analytic framework developed from a number of international curriculum and reform documents. A unique NOS profile was compiled for each case. Analyses of the students' NOS views revealed that their understandings did not develop uniformly for all five aspects of NOS investigated. It was found that the students' responses were rich and represented a range of views about each of

the five NOS aspects. Analyses of the internal coherence of the students' NOS views revealed a number of instances of complexity and incoherence, which included students' descriptions of border-crossing experiences (e.g., conflicts between what was taught in school science as opposed to knowledge presented at home). Overall, the results of the NOS analyses drew attention to the complexity of what constitutes an informed understanding of NOS.

For the second part of the study, students' views of the natural world were elicited by means of structured interviews and semi-structured follow-up interviews. The interview transcripts were analysed by means of a carefully validated coding procedure in order to create a concept map and a descriptive narrative for each student. An individual worldview profile was then compiled for each case. Results of the analyses of the students' views of the natural world revealed that they defined Nature as being distinct from people and/or human activity. Furthermore, the students described diverse and complex views regarding each of the four worldview descriptions investigated (i.e., epistemological, ontological, emotional and status descriptions). Analysis of the internal coherence of the students' views of Nature revealed a number of instances of complexity and incoherence, which included descriptions of border-crossing experiences (e.g., explicit conflicts between personal religious views and science). Overall, analysis of the students' views of the natural world reflected the inherent complexity of the concept of Nature.

For the third part of the study, systematic and structured analyses of coherence, both within and between the students' views of NOS and their views of Nature, were conducted. These coherence analyses were carried out by applying Thagard's (1989, 1992, 1994, 2006) explanatory coherence principles (i.e., symmetry, contradiction, explanation, competition, and system incoherence, as well as an additional principle of system complexity). There was found to be coherence between the students' definitions of Nature and their descriptions of the kinds of work that scientists do and the aims/purpose of science. Links (both coherent and incoherent) were also identified between students' views relating to the four worldview descriptions (i.e., epistemological, ontological, emotional, and status descriptions) and the five NOS aspects (i.e., tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative/creative). Cross-case analyses of these various coherent and incoherent links yielded some general insights into the relationship between the students' views of NOS and their descriptions of the natural world, and drew attention to the complex relationship between NOS and worldview. Further in-depth analyses involved the examination of coherent links between students' naive views of NOS and their views of Nature, and of incoherent links between students' informed NOS views and their views of Nature. A number of issues were highlighted that science teachers are recommended to address in the classroom in order to help their students to develop a more informed understanding of NOS. These issues included, for example, the role/purpose of science and the nature of scientists' work, natural diversity and patterns in Nature, the limits of people's knowledge of the natural world, truth/proof and making sense of uncertainties and lack of evidence in science, the role of imagination/creativity in science, the reliability of scientific knowledge, disagreements amongst scientists, and the existence of alternative knowledge frameworks in explanations about Nature. Due to a) instances of internal complexity and incoherence within the students' NOS views and within their descriptions of Nature, b) incoherent links between these two domains, and c) explicit conflicts and compromise views articulated by the students, it was concluded that the Grade Six students' views were not coherent overall.

A number of implications and recommendations for science education researchers and science teachers arose from the findings of this study. These concerned the need to record and present detailed and nuanced accounts of students' views, and to reflect upon and discuss with students the inherent complexity of the concepts of NOS and Nature. A number of possible avenues for future research were also identified.

Exploring the relationship between students' NOS views and their worldviews has been identified as an area of much-needed research in science education (N.G. Lederman, 2007) and, prior to the present study, there was no established methodology for exploring this relationship. This study therefore contributes to current knowledge in science education on multiple levels. Rich data were collected of the views of carefully selected South African Grade Six students concerning NOS and the natural world. Little research to date has involved elementary students' views of NOS, particularly in South Africa. Moreover, few studies have focussed on students' views of the natural world, although this component of worldview is of particular interest in science education. The present study thus contributes to our understanding of the little-known relationship between students' views of NOS and their views of the natural world. Furthermore, a novel methodology was employed in exploring the coherence of these two domains.

Keywords: Nature of science (NOS), Worldviews, Nature, Coherence, Elementary science, Grade Six, South Africa

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LIST OF ABBREVIATIONS

AAAS	American Association for Advancement in Science
DoE	Department of Education
FET	Further Education and Training
GET	General Education and Training
HOD	Head of Department
NCS	National Curriculum Statement
NOS	Nature of Science
NRC	National Research Council
NSTA	National Science Teachers' Association
SES	Socio-economic status
UCT	University of Cape Town
WCED	Western Cape Education Department

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INTRODUCTION

Overview

In this South African study, the coherence of Grade Six students' understanding of the nature of science (NOS) and their views of the natural world was investigated. This relationship was explored by means of an in-depth multiple case study of fourteen students. Rich qualitative data were analysed in regard to individuals' views of NOS and their views of the natural world. These data were collected by means of written questionnaires and interviews. A novel methodology was then employed in analysing the coherence within and between these two domains, namely, explanatory coherence theory.

Background and rationale

> Imagine the first day of a science class. A student walks up to the teacher and says, ‗Science is about the natural world, right? So before we start let me tell you what I believe about the natural world. After all, everything you say in this course, I will hear through the filter of my own viewpoint...' (Cobern,1993:949)

Students bring with them into the science classroom their own ways of looking at the world that are representative of their social and cultural environments as well as of their personal experiences. Moreover, their ways of knowing may or may not be compatible with the nature of science or the way science is generally taught in the science class (O. Lee, 1999).

One of the major goals of science education is to develop students who are scientifically literate (American Association for Advancement in Science [AAAS], 1989, 1993; Laugksch, 2000; N.G. Lederman, 2007; Murcia, 2007; National Research Council [NRC], 1996). Scientific literacy includes possessing an adequate understanding of the nature of science, the scientific enterprise, and the role of science in society and personal life (Hodson, 2009; Murcia, 2009; [NRC], 1996). For approximately 100 years, the construct ‗nature of science' has been advocated as an important goal for students studying science (N.G. Lederman, 2007; N.G. Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). Nature of science (NOS) refers to the values and beliefs inherent in scientific knowledge and its development (J.S. Lederman & Lederman, 2005a). Science education researchers have reached consensus over NOS understandings that are relevant and accessible to students in Grades R-12 (J.S. Lederman & Lederman, 2005a), but research in science education has found that individuals generally hold inaccurate NOS views (Abd-El-Khalick, 2005; Abd-El-

Khalick, Bell & Lederman, 1998; Akerson & Abd-El-Khalick, 2003; Akerson & Volrich, 2006; Kang, Scharmann & Noh, 2005; Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2006; Kawasaki, Herrenkohl, & Yeary, 2004; Kim & McKinney, 2007; N.G. Lederman, 2007). There are a number of possible factors influencing students' views of NOS, and one such factor is their worldviews (Hodson, 2009; N.G. Lederman, 2007). The worldview of a people is their way of looking at reality and their way of thinking about the world, including how they think about themselves, about their environments, and so forth (Kearney, 1984). Science educators are aware that students' learning in science is influenced by the worldviews commonly held in their socio-cultural environments (O. Lee, 1999).

Moreover, learning, that is, the acquisition of new knowledge and understandings, involves conceptual change in the mind of the student (Thagard, 1992). The nature of conceptual change that takes place during learning is determined by the extent to which the new ideas and explanations being taught are consistent with students' existing knowledge and understanding (Ausubel, 1967, 1968; P.W. Hewson, 1982; Posner, Strike, Hewson & Gertzog, 1982; Thagard, 1994). This is termed *explanatory coherence* (Thagard, 1992). Indeed, it can be considered that meaningful learning in science presupposes students who enter the classroom with beliefs about the world that are compatible with science as it is taught in the classroom (Cobern, 1993). Consequently, in the science classroom, developing connections with students' prior knowledge—especially with knowledge traditionally thought of as external to science—is important if students are to have a critical engagement with science (Cobern, 1994; Cobern & Loving, 2002; P.W. Hewson, 1982, M.G. Hewson & Hewson, 1989; Jegede, 1995; Posner et al., 1982).

Problem statement

At present, the exact nature of the relationship between individuals' worldviews (in particular, their existing ideas about the natural world) and their NOS views (i.e., epistemological ideas about science) is unknown (N.G. Lederman, 2007; Liu & Lederman, 2002), and this relationship thus constitutes an area of much-needed research (N.G. Lederman, 2007). Moreover, little NOS research has been conducted involving elementary school students (Akerson & Volrich, 2006; Conley, Pintrich, Vehiri, & Harrison, 2004; Kang et al., 2005), especially in South Africa (Laugksch, 2003). As there is no established methodology for analysing this relationship, there exists a need to develop a means of studying coherence between views of NOS and views of Nature, in order to expand this research domain.

Aims and objectives

The aim of this study was to contribute towards a greater understanding of the possible relationship between NOS views and a particular component of worldview, namely, views of the natural world. To this end, the researcher aimed to generate and analyse rich data of the views of a selection of South African Grade Six students (i.e., 11-12 years old) in regard to NOS and the natural world. An additional objective was to use a novel research methodology for exploring coherence, and subsequently, to explore—in-depth—the coherence within and between the students‘ views of NOS and of Nature.

Research questions

The present study was designed to answer the following main research question:

How do South African Grade Six students' views of the nature of science (NOS) cohere with their views of the natural world?

In order to answer this question, the study was divided into three parts, and the main research question was addressed by answering sub-questions relating to each of these three parts:

1. *What views of NOS do the Grade Six students hold, and what are students' levels of understanding about each NOS aspect?*

The students‘ views of NOS were studied by eliciting their views of the nature of scientists‘ work and the role/purpose of science, and more specifically, by analysing the students‘ levels of understanding about five particular aspects of NOS (i.e., tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative/creative)—in order to be able to compare their individual NOS profiles. The internal coherence of the students‘ NOS views was also examined.

2. *What views of the natural world do the Grade Six students hold?*

The students‘ views of Nature were studied by analysing their definitions of Nature, and their views of the natural world relating to four particular worldview descriptions (epistemological, ontological, emotional, and status)—in order to conduct a comparison of students‘ individual worldview profiles. The internal coherence of the students‘ views of the natural world was also examined.

3. *To what extent do the students' views of NOS and their views of the natural world cohere with one another?*

Coherence between the students‘ views of NOS and their views of Nature was explored by identifying coherent and incoherent links between their views of each domain, examining the relationship between these various links and the students‘ levels of understanding about NOS, and then finally, determining the overall coherence of the students‘ views.

Assumptions

It is assumed that students‘ worldviews, which are influenced by their social and cultural backgrounds, influence their views of the natural world, and that these views, in turn, influence students‘ views of the nature of science (NOS).

Significance of the study

In order to achieve the important educational goal of scientific literacy, students need to develop informed views of the nature of science (NOS). It has been suggested that students‘ NOS views are influenced by their worldviews, and that ―a knowledge of what teachers and students bring into class is critical in situating the teaching-learning process within a meaningful context" (Ogunniyi, Jegede, Ogawa, Yandile & Oladele, 1995:818). Therefore, in order to inform teaching practices related to NOS, there exists a need to explore the extent to which students‘ NOS views cohere with their worldviews and, in particular, with their views of the natural world. The present study therefore contributes to other knowledge by providing rich empirical data concerning the views of selected elementary school students in South Africa, regarding the nature of science (NOS) and the natural world, and regarding the coherence of these two domains. Furthermore, as there exists no established methodology for conducting such an investigation, a novel approach is explored as a means of examining the coherence of these two domains.

Description of the context of the study

The Western Cape is one of South Africa‘s nine provinces, and the present study was conducted in its capital city, Cape Town. Education in the Western Cape is overseen by the Western Cape Education Department (WCED). In Cape Town, elementary students can attend one of 130 schools. The majority of these schools are public schools (96 schools) (Western Cape Education Department [WCED], 2011), which are largely state-funded by means of subsidised teaching posts (Hofmeyer, 2000). The remaining schools are independent schools (34 schools) (WCED, 2011). Independent schools are privately owned, are typically better resourced and have a lower student-teacher ratio than public schools (Hofmeyer, 2000). A national curriculum, known as the National Curriculum Statement (NCS), is currently being implemented in all public schools (and in the majority of independent schools).

Schooling in South Africa begins in Grade R (Reception year) and is compulsory for students until Grade Nine, with the last year of schooling being Grade 12. These thirteen years of basic education form part of the General Education and Training (GET) band (Grades R-9) and Further Education and Training (FET) band (Grades 10-12). In the GET band, formal assessment of students takes place at a national level at the end of each of its three phases, that is, at the end of the foundation phase (Grades R-3), at the end of the intermediate phase (Grades 4-6), and at the end of the senior phase (Grades 7-9) (DoE, 2002b, 2011).

The focus of the present study was on Grade Six students in the intermediate phase of the GET band. In this phase, the NCS comprises eight core learning areas—one of which is the Natural Sciences learning area.[1] The aim of the Natural Sciences learning area is to promote scientific literacy by developing students' science process skills, developing students' understanding of scientific concepts and their knowledge of the natural world, as well as promoting students' understanding of the relationship between science, technology and society—including an understanding of science as a human activity and an understanding of the history of science (DoE, 2002a, 2002b).

In the policy document for the Natural Sciences learning area (DoE, 2002a), it is described how students in South African classrooms hold a variety of different worldviews. More significantly, questions are raised regarding the impact of students' worldviews on their learning in science (DoE, 2002a) (Chapter 2, page 30). The present study was designed to explore the answers to such questions.

Grade Six as the focus grade level of the students

The present study focussed on the views of Grade Six students for a number of reasons, which are related to the level of development, and to the teaching and assessment of students, in elementary school. By the time students reach Grade Six, they have been exposed to a number of years of formal science teaching. As mentioned above, in South Africa, students in Grade Six are in the final year of the Intermediate Phase of the General Education and Training Band (DoE, 2002b, 2011), and all Grade Six students are formally assessed in terms of knowledge and skills at the end of this year by means of common assessment tasks. It has been found that Grade Six students possess their own epistemologies about science (Kang et al., 2005)—albeit typically naïve NOS

[1] The other seven learning areas are: Languages, Mathematics, Social Sciences, Arts and Culture, Life Orientation, Economic and Management Sciences, and Technology (DoE, 2002).

views—and that they have adequate linguistic abilities to express their thoughts in writing (Kang et al., 2005). Moreover, Grade Six students‘ epistemologies can be improved (Smith, Maclin, Houghton & Hennessey, 2000)—in fact, it may be more productive to teach students about NOS at the elementary level than to remedy secondary students‘ inadequate understanding of NOS (Kang et al., 2005; Khishfe & Abd-El-Khalick, 2002). For these reasons, Grade Six was selected as the focus grade level for the present study. Moreover, as it is meaningful to work with elementary students in trying to improve their understandings of NOS, the implications of the findings arising from this study can be applied directly to them.

Overview of the research design

In order to collect rich data concerning the students‘ views of NOS and their views of the natural world, the study employed a qualitative research design involving a multiple case study methodology. Participants were purposively selected in order to maximise the diversity of views of the natural world represented by the students, whilst also controlling for a number of other factors that might impact on the students‘ views of NOS. Data concerning the students‘ views of NOS and of Nature were collected by means of written questionnaires and interviews. Analyses of coherence were then carried out, within and between the students‘ views of NOS and their views of Nature, by applying principles of explanatory coherence.

On a few occasions, the findings are presented numerically, in order to reflect the frequency of a particular result across the multiple cases being studied. However, this occasional use of numbers does not negate the description of the research design as qualitative.

Delimitations of the study

Delimitations of the research design and methodology relate to the collection and analysis of the data relating to NOS and worldview. Each of these will now be discussed, in turn.

The present study was designed to elicit the students‘ views pertaining to five specific aspects of NOS, namely, that scientific knowledge is tentative, empirically-based, theory-laden and subjective, culturally- and socially-embedded, and involves the use of imagination and creativity (Chapter 2, page 16). As such, the focus was on the students‘ epistemological views about science (i.e., the nature of scientific knowledge and how it is developed), rather than on students‘ conceptual knowledge of particular concepts in science (e.g., density, motion, electrostatics, etc.).

The study also was specifically designed to elicit students‘ views of the natural world, where Nature is a sub-category of one of the universal categories of worldview (i.e., NonSelf/Environment) represented in Kearney‘s (1984) logico-structural worldview model (Chapter 2, page 27). Unlike the majority of existing worldview studies, the present study did not seek to investigate students‘ conceptualisations of specific natural phenomena, or beliefs that form part of indigenous knowledge systems, nor was the focus on students‘ views about particular conservation-related issues.

It was beyond the scope of the present study to examine the reasons for why students held particular views of NOS and of the natural world, or the origins of students‘ views. Changes in the students‘ views were also not explored. This is because the aim of the study was to elicit students‘ *existing* views and to examine the *coherence* of the various ideas within their conceptual frameworks.

Clarification of terms[2]

Nature of science (NOS)

Nature of science (NOS) refers to the values and beliefs inherent in scientific knowledge and its development (J.S. Lederman & Lederman, 2005a). This includes an understanding that scientific knowledge is: (1) tentative (i.e., subject to change), (2) empirically based (i.e., based on and/or derived from observations of the natural world) and depends on human inference, (3) theory-laden and subjective, (4) socially- and culturally-embedded, and (5) involves the use of scientists‘ imagination and creativity (e.g., the invention of explanations) (J.S. Lederman & Lederman, 2005a).

Culture

In this study, the term ‗culture‘ refers specifically to subjective culture. Subjective culture concerns the norms and values that determine how people perceive, categorise, believe and value entities in their environment (Triandis, 1994). Values, beliefs, worldviews, and views of nature are attributes of culture (Aikenhead, 1996; Cobern, 1994, 1998, Ogunniyi et al., 1995; Thagard, 1994, Triandis, 1994). Cultural differences amongst people are typically described in terms of age, gender, language, religion, nationality, and social class (Triandis, 1994).

[2] The definitions of terms have been organised according to the structure of the thesis, and not alphabetically (e.g., nature of science, culture, worldview and views of the natural world, coherence, etc.).

Worldview

Worldview refers to the set of beliefs a person holds about the basic nature of reality (Emereole, 1998; Kearney, 1984; Ogunniyi et al., 1995). Worldview concerns how people think about themselves, their environments, the relationships between the two, and so forth. The present study drew upon Kearney‘s (1984) logico-structural model of worldview, and focussed specifically on one component of worldview that is particularly relevant for science education, namely, students‘ views of the natural world.

Indigenous knowledge also forms part of worldview, but the two terms are not synonymous (Keane, 2008). Indigenous knowledge refers to knowledge about the natural world that has originated in indigenous cultures, that is, outside of conventional Western science (Hodson, 2009; Kawagley, Norris-Tull, & Norris-Tull, 1998). In science education, studies concerning indigenous knowledge typically focus on individual‘s understandings about particular natural phenomena (e.g., medicinal healing, the origin of lightning and of rainbows, etc.) (e.g., Webb et al., 2006), and on comparing different culturally-based explanations about Nature (e.g., Schultz, Unipan & Gamba, 2000).

The natural world

The natural world is also sometimes referred to as the natural environment, or simply, Nature (Cobern, 1991). In the present study, Nature is spelled with a capital letter in order to differentiate its meaning from some homonyms that also appear in the thesis (e.g., references to the nature of science, or to the nature of the questions employed in a data collection instrument, or to the exploratory nature of this study). As mentioned above, views of the natural world constitute one component of a person‘s worldview.

Definitions of Nature vs. Worldview descriptions

On the one hand, the students‘ definitions of Nature primarily concerned their views of that which is considered to form part of the natural world as opposed to that which is not part of Nature. Such views were typically elicited in response to initial questions that were posed to them during their worldview interviews, for example, ―What is Nature?”, ―What is not part of Nature?”, and ―Please explain why you say so?”

On the other hand, worldview descriptions refer to four analytic categories, taken from Cobern‘s (1991, 2000b) worldview research design, namely, epistemological descriptions, ontological descriptions, emotional descriptions, and status descriptions of the natural world.

Epistemological & ontological views of the natural world

In the present study, references to epistemological views of the natural world relate specifically to the students‘ descriptions of what we can and do know about Nature, and how we come to know it (e.g., the extent to which Nature is understandable and predictable).

References to ontological descriptions of the natural world relate specifically to the students‘ views of the nature of reality, that is, whether Nature is comprised merely of material structures and is understood in terms of physical causation, or whether the students believe there to be super-natural involvement in Nature. The latter belief refers to transcendental purposes when describing natural events and phenomena.

Coherence

Coherence concerns the relationship between the various views that people hold within their conceptual frameworks (Thagard, 1994), and the extent to which ideas ―hold together” (Thagard, 1989:436). Ideas that agree with one another are *coherent*, whereas those that contradict one another are *incoherent*. In the present study, explanatory coherence principles of symmetry, contradiction, explanation and competition were used in identifying coherent and incoherent links between the students‘ views of NOS and their views of the natural world. Principles of system complexity and system incoherence were used in identifying instances of complexity and incoherence within each of these two domains.

General notes about the thesis

As already mentioned (page 6), in the present study a multiple case study design was employed in order to generate rich data of the students‘ views, and in order to be able to analyse these data in-depth. Space limitations unfortunately do not allow for all these data to be included in the main body of the thesis. Consequently, extensive use has been made of appendices in providing evidence to support the claims and discussions presented in the main text. In order to ensure easy reference to the data provided in the appendices, the numbering of the various appendices corresponds with the chapter numbers. For example, the appendices related to Chapter Three have been numbered Appendix 3.1, Appendix 3.2, and so forth.

In order to protect the identities of the students, their names have been replaced with gender- and culture-appropriate pseudonyms.

In some places in the thesis, and in particular, within extracts from the students' original statements, particular words and/or phrases have been typed in bold or underlined. This has been done in an attempt to help the reader to locate salient portions in these extracts.

In Chapters Four and Five, in describing the students' views, the terms *diverse* and *rich* are used. Although these two terms might appear similar in meaning, they are used distinctly in the present thesis. That is, where students' views are described as being *diverse*, this relates to differences that are apparent *between* the various cases. However, where students' views are described as being *rich*, this does not involve a cross-case comparison. Instead, richness concerns the multiplicity of meanings found *within* an individual's views.

There is a paucity of research literature in science education concerning elementary school students' views of the natural world, and their views of NOS, both in general and particularly within the South African context. Moreover, the relationship between these two domains remains largely unexplored (Chapter 2, page 19). Therefore, in discussing the results of the present study (i.e., Chapter 5) scant reference is made to existing research findings (Chapter 5, page 215).

Overview of chapters

Chapter Two (page 13), which follows next, presents the conceptual and theoretical framework for the study. The framework involves a review of current research literature relating to scientific literacy, the nature of science (NOS), worldview and the natural world (i.e., Nature), the relationship between worldview and factors related to culture, cross-cultural learning in science education, and conceptual change and a coherence view of learning. Chapter Three (page 53) details the methodology employed in the collection and analysis of the data in the present study. This third chapter includes an overview of the research design, an explanation of the strategy for selecting participants, a description of the design and administration of the various instruments employed in collecting data, and an explanation of how the data collected by means of these various instruments were analysed. The results of the study are presented in Chapter Four (page 105). The study comprises three components (i.e., relating to the students' views of NOS, the students' views of the natural world, and the coherence of these two domains), and therefore the results pertaining to each of these three components are presented in separate parts (i.e., Part One:

Views of NOS; Part Two: Views of the natural world [i.e., Nature]; and Part Three: Coherence). The results are then discussed in Chapter Five (page 211). The discussion is presented in three parts, in correspondence with the previous chapter. Chapter Five also includes a description of the contributions of the study, and a summary of the implications of the findings in regard to science teachers and science education researchers. Finally, concluding remarks are presented.

Chapter Two

CONCEPTUAL AND THEORETICAL FRAMEWORK

The conceptual and theoretical framework for the present study involves a number of inter-related components. To begin with, scientific literacy is accepted as a major goal of science education, and this includes students developing adequate understandings of the nature of science (NOS). A review of the research literature concerning NOS is therefore provided first. This is followed by a discussion of the notion of worldview, as it is expected that students‘ worldviews impact on their views of NOS. The particular worldview component of interest in science education concerns students‘ views of the natural world, and therefore the next section provides a summary of the concept of Nature. The broader notion of worldview is a cultural construct, and therefore an overview is provided of the relationship between worldview, religion, identity and culture. This is followed by a discussion of cultural border-crossing as it pertains to students‘ experiences in learning science. Finally, there is a review of the research literature relating to conceptual change and meaningful learning and, more specifically, a coherence view of knowledge. Explanatory coherence theory is presented as a useful means of analysing the relationship between students‘ worldviews and their NOS views. Figure 2.1 provides a diagrammatic overview of the theoretical framework that is presented in this chapter.

Scientific literacy

In this section, the educational aim of scientific literacy is the starting point of a discussion of the nature of science (NOS) as an important component of the science curriculum. An outline is then provided of the findings from NOS research to date. This includes work that has been undertaken at elementary school level, in particular, research undertaken in South Africa, and research concerning the relationship between NOS and worldviews. The review of NOS literature with these particular foci is then followed by a discussion of assessment with regard to the nature of science.

One of the principal goals of science education is to develop scientifically literate individuals (AAAS, 1989, 1993; Laugksch, 2000; N.G. Lederman, 2007; Murcia, 2007; NRC, 1996). Scientific literacy is considered by some to be ―an ill-defined and diffuse concept" (Laugksch, 2000:71). Furthermore, some scholars distinguish between different scientific literacies for different socio-cultural contexts (e.g., practical, civic, cultural and environmental scientific literacy) (Hodson, 2009). However, there seems to be agreement that scientific literacy is broadly concerned with

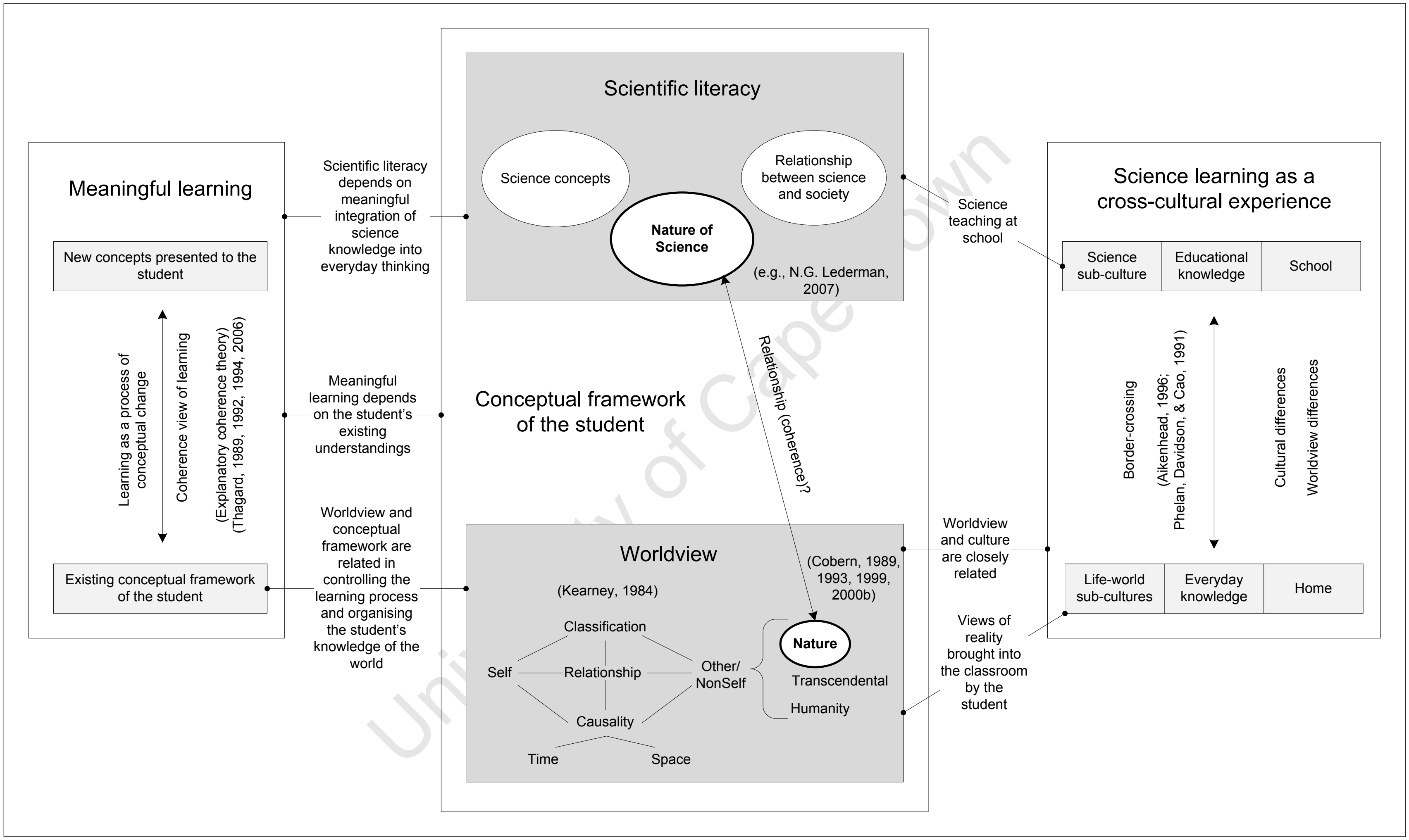


Figure 2.1: Diagrammatic overview of the conceptual and theoretical framework for the present study

acquiring knowledge of important and enduring science concepts, as well as an understanding of the nature of science, and of the relationship between science and society (Hodson, 2009; Murcia, 2009; NRC, 1996).

In addition to these three knowledge dimensions, scientific literacy concerns a way of thinking and acting (Murcia, 2009). People who are literate in science are not necessarily able to do science, but are able to use the habits of mind and knowledge of science that they have acquired to think about and to make sense of the many ideas, claims, and events that they encounter in everyday life. Critical scientific literacy includes the ability to distinguish between the ways in which scientific knowledge differs from other forms of knowledge (e.g., religious, philosophical, aesthetic and psychological knowledge) and consequently an understanding of when to apply scientific ways of thinking (Hodson, 2009). Scientific literacy enhances a person‗s ability to observe events perceptively, to reflect on them thoughtfully, and to comprehend explanations offered for them, thereby providing the person with a basis for making decisions and taking action (AAAS, 1993; Hodson, 2009). That is,

> When people know how scientists go about their work and reach scientific conclusions, and what the limitations of such conclusions are, they are more likely to react thoughtfully to scientific claims and less likely to reject them out of hand or accept them uncritically…The images that many people have of science and how it works are often distorted…the study of science as a way of knowing needs to be made explicit in the curriculum. (AAAS, 1993:3)

Indeed, an understanding of the nature of science is an important component of scientific literacy (AAAS, 1989, 1993; Allchin, 2011; Hodson, 2009; Holbrook & Rannikmae, 2009; Hurd, 1998; Karatas, Micklos, & Bodner, 2011; N.G. Lederman, 2007; Murcia, 2007; NRC, 1996). Consequently, helping students to develop informed views of NOS has been and continues to be a central goal for kindergarten through to Grade 12 (K-12) science education and for science education research (Dekkers, 2006; N.G. Lederman, 1999, 2007; N.G. Lederman et al., 2002). This educational goal is reflected in international reform and curriculum documents (e.g., AAAS, 1989, 1993; NRC, 1996) as well as in the National Curriculum Statement (NCS) currently being implemented in South African schools. In particular, the Natural Sciences Learning Area in the NCS (Grades R to 9) promotes scientific literacy by

> ...the development and use of science process skills in a variety of settings; the development and application of scientific knowledge and understanding; and appreciation of the relationships and responsibilities between science, society and the environment… Careful selection of scientific content, and use of a variety of ways of teaching and learning science, should promote understanding of science as a human activity; the history of science; and the contribution of science to social justice and societal development. (DoE, 2002a:4,5)

Some scholars argue there is no such thing as a —universal” science or image of science (Kawagley et al., 1998; Rudolph, 2000; Stanley, & Brickhouse, 1994, 2001). Others point to the vitality of science, including the notion that NOS itself is an evolving concept (Bianchini & Colbourn, 2000; Kang et al., 2005; N.G. Lederman, 2007), and that variations exist amongst the practices of individual scientists (Jenkins, 1996; Wong, 2002). There is also ongoing debate about the status of indigenous science in relation to Western science (e.g., Aikenhead & Ogawa, 2007; Cobern & Loving, 2001; Kawagley et al., 1998; Lynch, 1998; Ogawa, 1995; Snively, & Corsiglia, 2001). Some scholars argue against the formulation of a prescribed list of NOS items or a set of —acquired beliefs” about NOS (Hodson, 2009:20) from the viewpoint that NOS includes more than an understanding of the characteristics of scientific knowledge (i.e., epistemological considerations). They contend that NOS also —encompasses the characteristics of scientific inquiry, the role and status of the scientific knowledge it generates, how scientists work as a social group, and how science impacts and is impacted by the social context in which it is located” (Hodson, 2009:21).

Nonetheless, consensus has been reached about what image of science should be presented to learners, sometimes referred to as the science worldview (Cobern, 1999) or the sub-culture of science (Aikenhead, 2001; Jegede & Aikenhead, 1999). This generally accepted view of science includes an understanding that scientific knowledge is tentative (i.e., subject to change), subjective and theory-laden, empirically based (i.e., based on and/or derived from observations of the natural world), socially- and culturally-embedded, and depends on human inference, imagination and creativity (i.e., involves the invention of explanations) (N.G. Lederman, 2007). First, an informed view of the tentative aspect of NOS involves an understanding that scientific knowledge is never absolute or certain—scientific claims change as new evidence is found, or when existing evidence is interpreted in a new way. Second, informed views of the subjective and theory-laden aspect of NOS concern the notion that not all scientific knowledge has been proven, and that the ways in which scientists conduct investigations and interpret their findings is influenced by their previous knowledge, training, experiences, beliefs and expectations. Third, an informed view of the empirically-based aspect of NOS involves the recognition that science is limited to naturalistic methods and explanations, and scientists formulate and test their explanations of nature by means of observation, experiments, accurate measurements, and so forth. Fourth, informed views of the socially- and culturally-embedded aspect of NOS concern the notion that science is a human endeavour which is influenced by a larger social and cultural context, including political, socio-economic, philosophical, and religious elements, as well as the existing state of scientific knowledge. Fifth, an informed view of the imaginative and creative aspect of NOS relates to an acknowledgment that science involves the invention of explanations and solutions to problems, which requires scientists to be creative in their work. Two additional aspects of NOS concern the distinction between observation and inference, and the functions of, and relationships between, theories and laws (J.S. Lederman & Lederman, 2005a). However, it has been found that the latter is not easily addressed in the elementary science curriculum (Akerson & Hanuscin, 2007).

It is argued that the NOS aspects outlined above are accessible and relevant to Grade R-12 students‘ everyday lives, and they are at a level of generality that avoids any contentious arguments (Akerson & Donelly, 2010; J.S. Lederman, & Lederman 2005a; N.G. Lederman, 2007; N.G. Lederman et al., 2002; Khishfe & Abd-El-Khalick, 2002). Elementary school is arguably a crucial time for developing and restructuring students‘ epistemological views about science (i.e., their NOS views) (Conley et al., 2004; Smith et al., 2000). Desired learning outcomes relating to NOS are detailed per Grade and per NOS concept in a number of science curriculum and reform documents, including those published by the American Association for Advancement in Science (AAAS) (1989, 1993), the National Research Council (NRC) (1996), the National Science Teachers‘ Association (NSTA) (n.d.), and—to a lesser degree—in South Africa‘s NCS.

Elementary school students possess their own epistemologies about science (Kang et al., 2005) and it is possible for young students to develop rich views of science (Akerson & Donelly, 2010). Their NOS understandings can develop and be improved with appropriate instruction (Akerson & Donelly, 2010; Akerson & Hanuscin, 2007; Akerson & Volrich, 2006; Carey, Evans, Honda, Jay, & Unger, 1989; Conley et al., 2004; Kawasaki et al., 2004; Khishfe, 2008; Smith et al., 2000). In fact, it may be more productive to teach students about the nature of science at elementary school level—and throughout science teaching over a period of time (Khishfe & Abd-El-Khalick, 2002)—than it is to remedy the inadequate NOS understandings of students at high school level (Kang et al., 2005). This is because ―the attitudes and values established toward science in the early years will shape a person‘s development of scientific literacy as an adult" (NRC, 1996:22). However, in order to improve students‘ understanding of NOS, teachers first need to understand what the students already know about the nature of science (Akerson & Abd-El-Khalick, 2005), and they need to be cognisant of the potential cultural barriers to learning science that might be experienced by students from different backgrounds (Liu & Lederman, 2002; Sutherland & Dennick, 2002).

Nature of science (NOS)

The nature of science is recognised as an important component of science teaching and learning, and specific aspects of NOS have been identified as the key aspects to be taught when developing students' NOS views. Indeed, NOS continues to be a major focus amongst science education researchers.

A number of NOS studies have been conducted in the field of science education research. Repeatedly, studies have found that individuals hold naïve views about science and what it is that scientists do (Akerson & Abd-El-Khalick, 2003; Akerson & Volrich, 2006; Kang et al., 2005; Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2006; Kawasaki et al., 2004; Kim & McKinney, 2007; N.G. Lederman, 2007). Individuals' NOS views have also been found to be stubborn, that is, resistant to change (Kang et al., 2005; Khishfe & Abd-El-Khalick, 2002). Attempts to improve individuals' NOS views have found improvements in NOS understanding to be poorly retained (Akerson, Morrison & McDuffie, 2006), and individuals had difficulty applying their NOS understandings in differing contexts (Akerson & Abd-El-Khalick, 2003; Khishfe & Abd-El-Khalick, 2002). Science education research also reports on the distinction between personal knowledge and declarative knowledge (Hogan, 2000), and the differences between the articulated curriculum and the enacted curriculum. The negative impact of diminished curriculum expectations on students' NOS understandings (Metz, 2004) has been investigated, as well as the impact of various teaching strategies and course contents on individuals' NOS views. These teaching strategies have concerned, for example, an integrated approach to NOS teaching compared to a non-integrated approach (Khishfe & Lederman, 2006), and an implicit approach compared to an explicit-reflective approach to teaching about NOS (Akerson & Volrich, 2006; Khishfe & Abd-El-Khalick, 2002; Schwartz, Lederman & Crawford, 2004).

A number of NOS studies have investigated possible factors influencing the translation of teachers' NOS views into classroom practice, including, parents (Barton et al., 2001), school context (Abd-El-Khalick et al., 1998; N.G. Lederman, 1992), teachers' pedagogic content knowledge (Schwartz et al., 2004), the view of science that is presented to learners (Brickhouse, 1990), language (Sutherland & Dennick, 2002), and worldviews (Liu & Lederman, 2003). Factors that appear to exert the greatest influence on students' NOS understandings include the teacher's instructional behaviour, and possibly students' academic abilities (Conley et al., 2004; N.G. Lederman, 2007) and cultural backgrounds (Sutherland & Dennick, 2002), including their worldviews (Liu & Lederman, 2003; N.G. Lederman, 2007). The teacher's instructional behaviour includes dimensions relating to subcultures of the school and the classroom (N.G. Lederman, 1992, 2007). Particular dimensions here include the teaching context, administrative policies, curriculum constraints, pressure to cover content (Abd-El-Khalick et al., 1998; N.G. Lederman, 1992), the teacher‘s instructional skills, approach and style of instruction, language and the implicit messages embedded within it, the teacher‘s personality and rapport with the class, classroom environment (N.G. Lederman, 2007), classroom management, teachers‘ knowledge of NOS subject matter (Schwartz & Lederman, 2002), lack of resources and experiences for assessing students‘ NOS understandings (Abd-El-Khalick et al., 1998), discomfort with understandings of NOS (Abd-El-Khalick et al., 1998), and concerns for students‘ abilities and motivation in learning about nature of science (Duschl & Wright, 1989). Teaching experience and academic background variables of teachers do not appear to impact learners‘ NOS views; neither does the implicit classroom environment (N.G. Lederman, 2007). Interestingly, no direct relationship has been found between teachers‘ own NOS views, as determined by teachers‘ beliefs (F.W. Bloom, 1989), and students‘ NOS views (N.G. Lederman, 1992; Lederman, 2007). Teachers‘ NOS views also do not appear to be directly related to their classroom practice (N.G. Lederman, 1992, 2007).

Regarding teachers‘ instructional practice, the greatest impact on students‘ NOS views has been found to be the use of an explicit and reflective approach to teaching of NOS (e.g., Abell, Martini, & George, 2001; Akerson, Abd-El-Khalick, & Lederman, 2000; Bianchini & Colbourn, 2000; N.G. Lederman, 1999, 2007). There is also a possible relation between students‘ academic abilities and their understandings of NOS (Conley et al., 2004; N.G. Lederman, 2007), that is, stronger students are more likely to hold more informed views of the nature of science than their weaker classmates. Academic performance itself is influenced by a number of factors, including ―opportunity to learn” (Floden, 2002; Reeves, 2005) and the students‘ socio-economic backgrounds (Anderson, Case & Lam, 2001; Case & Deaton, 1999). NOS studies have identified other variables relating to the subcultures of family, peers, and community (Dhingra, 2003) that may impact students‘ NOS views. In addition to socio-economic status, factors include exposure to science via students‘ cultural background (Liu & Lederman, 2002) and mass media—for example, informal television viewing (Dhingra, 2003). Language differences amongst students do not appear to have a significant impact on students‘ understandings of the nature of science (Sutherland & Dennick, 2002). Finally, worldview (N.G. Lederman, 2007)—as an element of culture—is thought to influence students‘ understandings of NOS (Hodson, 2009). In fact, N.G. Lederman (2007) identifies this as a critical line of research that needs to be carried out:

> What is the influence of one's worldview on conceptions of nature of science?...Although much research on individuals‘ worldviews has been pursued, such research has rarely been directly and systematically related to views on NOS. One notable exception has been Cobern‘s work (2000b). It seems that NOS may be a subset of one‘s worldview or is at least impacted

> by one's worldview. Of primary importance is the relevance of this line of research for the teaching of NOS across cultures.

Few NOS studies have explored elementary students' views of the nature of science (Conley et al., 2004; Kang et al., 2005), and these studies have been mostly of upper elementary or middle school students (Akerson & Volrich, 2006). Consequently, there exists a need to further explore the NOS views of elementary students (Akerson & Abd-El-Khalick, 2005; Conley et al., 2004). Studies involving elementary school students have focussed on the effects of instruction on students' understandings about NOS (e.g., Akerson & Abd-El-Khalick, 2005; Akerson & Donelly, 2010; Akerson & Hanuscin, 2007; Akerson & Volrich, 2006; Carey et al., 1989; Carey & Smith, 1993; Khishfe, 2008; Khishfe & Abd-El-Khalick, 2002; Kim & McKinney, 2007). Other NOS studies have explored improvements in elementary school students' NOS views (e.g., Conley et al., 2004; Kawasaki et al., 2004; Khishfe, 2008), whilst others have compared the views of students at various grade levels (e.g., Akerson & Hanuscin, 2007; Kang et al., 2005; Leach, Driver, Millar, & Scott; 1997). One study involving Grade Sixes investigated students' views of the nature of engineers and engineering (Karatas et al., 2011). Although worldview has been identified as a possible factor influencing students' understanding of NOS (page 18), the relationship between elementary students' NOS views and their worldviews remains largely unexplored.

In fact, very little cross-cultural research has focused on elementary school students' NOS views, or on the relationship between students' NOS views and their worldviews. In one study, Sutherland and Dennick (2002) explored the NOS views of selected Cree (i.e., First American) and Euro-Canadian students in Grade Seven. They tested the possibility that the different worldviews of the two groups of students might influence their perceptions of science. Their findings indicated that, although science is equally foreign to Western and non-Western students, non-Western students experience greater cultural barriers to learning science than do Western students. Unfortunately the reliability of their results is questioned (Sutherland & Dennick, 2002). In another study, Liu and Lederman (2002) investigated the NOS views of Grade Seven Taiwanese students, but their findings generated more questions than answers. Specifically, their study raised questions regarding the factors, including worldview and social and cultural values, which influence how students develop informed NOS views. Liu and Lederman (2007) conducted a subsequent study involving Taiwanese pre-service elementary school teachers to explore the relationship between teachers' worldviews and their views of the nature of science. The results of the second study showed that there were indeed patterns between the teachers' worldviews and their NOS views, but that further work needed to be done in order to determine *how* worldview influences individuals‘ views of NOS.

Further to the paucity of research involving elementary students and/or concerning the relationship between NOS and worldview, little NOS research has been done within the South African context (Laugksch, 2003). With the exception of a few studies (e.g., Khishfe & Abd-El-Khalick, 2002; Kang et al., 2005; Liu & Lederman, 2002, 2007) all of the elementary NOS studies published to date (e.g., Akerson & Abd-El-Khalick, 2003; Akerson & Abd-El-Khalick, 2005; Akerson & Volrich, 2006; Carey et al., 1989; Meichtry, 1992; Smith et al., 2000) have been carried out in the United States of America or Europe (Holbrook & Rannikmae, 2009). In South Africa, NOS studies have generally involved teachers, or students at secondary and tertiary levels, with a typical focus on the impact of instructional courses on teachers‘ NOS views (e.g., Dekkers, 2004, 2005a, 2005b, 2006; Dekkers, Ogunniyi, Mosimege, & Marenga, 2005; Dekkers, & Mnisi, 2003; Ibrahim, 2005; Ibrahim, Buffler & Lubben, 2009; Laugksch, 2003; Linneman, Lynch, Kurup, Webb, & Bantwini, 2003; Ogunniyi, 1983, 2005; Webb & Cross, 2005; Webb, Cross, Linneman, & Malone, 2005). There is a paucity of research within the South African context concerning elementary students‘ understanding of NOS.

A vast array of instruments has been designed and implemented in studies investigating individuals‘ NOS views. N.G. Lederman (2007) provides an excellent overview of the various instruments and their strengths and limitations. In general, the validity of instruments purporting to assess NOS has been criticised on the grounds that each instrument assumes its interpretation of science to be the correct view (Cotham & Smith, 1981; N.G. Lederman, 2007). This criticism arises from the debate concerning a lack of consensus concerning NOS. However, as previously discussed (page 17), when working with students from Grades R to 12, the targeted aspects of NOS are at a level of generality that is not at all contentious. Besides this issue concerning the contents of various NOS tests, there appear to be two main issues concerning ―traditional” paper-and-pencil assessments of NOS. First, assessment instruments are interpreted in a biased manner. For example, N.G. Lederman and O‘Malley (1990) documented discrepancies between their own interpretations of students‘ written responses and the interpretations that surfaced from actual interviews of the same students. The problem of researchers interpreting responses differently than intended by the respondent exists at all age levels (i.e., from Grade R to adults), with increasing levels of uncertainty as the age of the respondent decreases (N.G. Lederman, 2007). For this reason, researchers should not abandon the interviewing of individuals about their written responses

(N.G. Lederman, 2007). Furthermore, instead of using quantitative NOS test scores simply to measure an individual‘s adherence to a particular conception of science, NOS researchers are advised to adopt a more qualitative approach that involves use the NOS scores to construct profiles of beliefs and knowledge (Ibrahim et al., 2009; Kang et al., 2005; Khishfe & Abd-El-Khalick, 2002; Meichtry, 1992; N.G. Lederman, Wade & Bell, 1998).

The second issue concerning some ―traditional" paper-and-pencil assessments of NOS is that they appear to have been poorly constructed (N.G. Lederman, 2007). Weaknesses include a lack of subscales, inappropriate cognitive levels of test items, and the amount of time needed to administer some of the instruments (N.G. Lederman, 2007). However, despite the specific weaknesses of various NOS instruments, these weaknesses appear to be insignificant, as the research conclusions derived from studies in which the instruments were employed are very consistent (N.G. Lederman, 2007).

Generally, regarding assessment of NOS, written forms of assessment are preferable to observation methodologies (N.G. Lederman, 2007). Open-ended written questionnaires elicit more in-depth data on individuals‘ NOS views, and therefore provide more meaningful insights than standardised pencil-and-paper type tests, such as those comprising Likert scale items (Khishfe & Abd-El-Khalick, 2002; N.G. Lederman et al., 1998). In addition to the administration of questionnaires, it is important to conduct interviews with respondents, not only to clarify what it is that they believe about the nature of science and to validate the researcher‘s analysis of respondents‘ NOS views (Kang et al., 2005; Khishfe & Abd-El-Khalick, 2002; Meichtry, 1992), but also in order that respondents can explicate the meanings of some of the terms they use (Khishfe & Abd-El-Khalick, 2002). Regarding analysis, J.S. Lederman (personal communication, September 13, 2006) advises against the numerical scoring of NOS questionnaire responses, rather advocating more qualitative approaches to the analysis and description of the data: This is because ―we are looking for what the students view and feel, [and] the best way to capture and assess these is to assign a category of understanding, [that is], naive, transitional or developing, and informed. Of course it would be easier to have a numerical scoring for the researcher but these would essentially be meaningless."

To date, few instruments have been designed to assess the NOS understandings of students in elementary school. A number of studies have employed the *Draw-A-Scientist-Test* (*DAST*) in attempting to gather data about elementary students‘ overall images of scientists (e.g., Huber & Burton, 1995; Sumrall, 1995). However, use of the *DAST* instrument reportedly presents methodological limitations (Hodson, 2009; Schibeci, 2006; Sumrall, 1995). Moreover, eliciting students' global perceptions of scientists purportedly does not enable in-depth analysis of students' views regarding specific aspects of NOS. In fact, N.G. Lederman's (2007) review of NOS assessment instruments includes only two questionnaires, namely, the *Modified Nature of Scientific Knowledge Scale (M-NSKS)* and the *Views of Nature of Science (VNOS)*. The *Modified Nature of Scientific Knowledge Scale (M-NSKS)* was developed by Meichtry (1992) for use with students in Grades Six to Eight. A total of 32 statements are presented in a Likert-scale response format. The *M-NSKS* test measures students' understanding that scientific knowledge is partially a product of human creativity, that it is tentative, and capable of empirical test, and that the specialised sciences contribute to an interrelated network of laws, theories and concepts (Meichtry, 1992). The *Modified Nature of Scientific Knowledge Scale (M-NSKS)* is a modified version of the *Nature of Scientific Knowledge Scale (NSKS)* test (Rubba, cited in N.G. Lederman, 2007) that was designed for assessing secondary students' understandings of NOS. According to N.G. Lederman (2007), the *NSKS* has generally been viewed positively by the research community, but there is reason for some concern about its reliability and face validity. Meichtry (1992) described a potential limitation of the study pertaining to the reliability of the *MNSKS* instrument employed, in that as the age of the students tested decreased, so too did the reliability of the instrument. Sutherland and Dennick (2002) acknowledged language barriers as a limitation of their study using the *NSKS* instrument. Moreover, Meichtry (1992) pointed out the need to supplement data collected by means of the written questionnaire with interviews conducted with the students being studied.

In order to avoid some of the concerns raised about ―traditional" paper-and-pencil assessments, and in an attempt to improve upon instruments such as *M-NSKS*, including recognition of a move towards the use of open-ended probes, N.G. Lederman and O'Malley (1990) developed and implemented a series of instruments named *Views of Nature of Science (VNOS)* for assessing the NOS views of learners and teachers (N.G. Lederman, 2007). *VNOS* is currently the most widely used NOS assessment instrument designed for use by science education researchers (Allchin, 2011). Different versions of *VNOS* (i.e., *VNOS-B, C, D, E*—and recently also *VNOS P*) were designed as variations and improvements upon the original *VNOS-A* (Lederman, 2007). Each *VNOS* instrument contains open-ended questions that focus on various aspects of NOS. Of particular relevance for the purposes of the present study is version D because of its developmental appropriateness and language specifically for elementary school students. *VNOS-E* (J.S. Lederman & Ko, 2003) was designed for very young students (i.e., Grades R-3), and has proved effective in accurately assessing elementary students NOS understandings (J.S. Lederman & Lederman, 2005b). Moreover, *VNOS-E* can be easily administered in less than one hour whilst still yielding the same results as the longer *VNOS-B* and *VNOS-C*. *VNOS-P* is the most recently developed instrument and it has been developed for students with limited reading and writing abilities. These recent versions of *VNOS* represent the first measure of NOS designed for such a young audience (N.G. Lederman, 2007; J.S. Lederman & Lederman, 2005a, 2005b). NOS aspects included in the *VNOS-E* and *VNOS-P* questionnaires include an understanding that scientific knowledge is tentative, subjective, empirically based, socially embedded, and depends on human imagination and creativity, as well as the distinction between observation and inference (J.S. Lederman & Ko, 2003). *VNOS-E* and *VNOS-P* also invite responses regarding the role of science, and the nature of experiments and the scientific method, as well as the role of models in science and the distinction between models and reality.

For the purposes of this study, the latest versions of the *VNOS* instrument (i.e., *VNOS-E* and *VNOS-P*) seemed the best choice to make in selecting an instrument for assessing Grade Six students' views of NOS. This is due to the improvements the *VNOS* suite of instruments make on previous NOS assessment instruments, the use of open-ended questions in the design of *VNOS*, the context-specific and developmentally appropriate nature of the questions, the use of age-appropriate language, and the reasonable time needed to complete the questionnaire. A comparison was made of the contents of each of the various *VNOS* instruments in order to finalise *VNOS-rs* that is the version being employed in the present study. The development of *VNOS-rs* for this study is described later (Chapter 3, page 72).

As already mentioned (page 19), the relationship between worldviews and NOS views remains largely unknown. The following section deals with the concept of worldview and, in particular, within the context of science education.

Worldview

The discussion of worldview presented here begins with a definition of the concept and an outline of two main schools of thought regarding worldview theory. Kearney's (1984) model of worldview is then described in more detail, as this was the worldview theory that guided the design of the present study. This is followed by an overview of worldview research that has been conducted within the context of science education.

Worldview theory has received increasing attention in science education (Cobern, 1991, 1996), and this attention reflects an awareness among science educators that students‘ beliefs in studying science are influenced by the worldview of their socio-cultural environments (O. Lee, 1999:189). Worldview can be described as a set of beliefs held consciously or unconsciously about the basic nature of reality and how one comes to know about it (Emereole, 1998; Ogunniyi et al., 1995). Kearney (1984:41) defines the worldview of a people as ―their way of looking at reality. Worldview consists of basic assumptions and images that provide a more or less coherent, though not necessarily accurate, way of thinking about the world.” The concept of worldview is central to education because it is closely related to the concept of knowledge (Proper, Marvin, Wideen & Ivany, 1988), where scientific knowledge is ―socially and culturally embedded” (Abd-El-Khalick et al., 1998). Moreover, the concept of worldview seems to be closely related to that of a cognitive map (Kawagley et al., 1998) in that a worldview provides a foundation upon which cognitive frameworks are built during the learning process (Cobern, 1989).

From the earliest days of their lives, students develop ideas/schemes about the natural world around them (Driver, Squires, Rushworth & Wood-Robinson, 1994; Hills, 1989; O. Lee, 1999), and these worldviews that they bring with them into the science classroom may affect how they make sense of scientific information (Allen & Crawley, 1998; M.G. Hewson, 1988). Cobern (1993:935) goes on to say that ―meaningful learning in the science classroom presupposes students who enter with beliefs about the world compatible with science as it is taught in the classroom”. Thus, how people see the world is very much of interest to both scientists and science educators (Cobern, 1996). Moreover, science teaching, because it deals directly with the natural world, plays a major role in shaping students‘ knowledge and worldviews (O. Lee, 1999; Proper et al., 1998). Unfortunately, according to Cobern (1996:589), ―science education as currently conceptualised fails to teach scientific understanding within the actual worlds in which people live their lives.” Worldview is the means by which students explain how and why things function as they do, interpret and organise their sensory experiences, and gauge the plausibility of new ideas that are presented to them. Therefore, in order for science education to be successful, science teachers need to understand the fundamental beliefs about the world that students bring with them to class and, in particular, what students believe about the natural world (Cobern, 1994, 1998). Worldview theory offers an approach to answering this question (Cobern, 1994).

Worldview theory can be discussed from two main schools of thought. On the one hand is Kearney‘s (1984) logico-structural model of worldview. Allen and Crawley (1998), George

(1999), O. Lee (1999), and Tsai (2001) have all published work on worldviews using Kearney‘s worldview theory, as has Cobern (1991, 1993, 1994, 1996). Cobern‘s work is of particular interest as it is situated within the field of science education research. In South African and African contexts, Lawrenz and Gray (1995) and Ogynniyi et al. (1995) have conducted investigations of worldview theory that draw upon Kearney‘s logico-structural model as well as on the work of Cobern.

On the other hand, Pepper (1970) identified six world hypotheses (i.e., animism, mysticism, formism, mechanism, contextualism, and organicism) based on a root metaphor theory. In both his masters dissertation (Kilbourn, 1976) and doctoral thesis (Kilbourn, 1980), Kilbourn developed an analytical scheme based on Pepper‘s world hypotheses to analyse the worldviews held by biology teachers and as well as the worldviews present in biology textbooks. Proper et al. (1988) considered the works of Roberts, Aoki and Sire (cited in Proper et al., 1988) as alternatives to Pepper‘s classification of worldviews and they judged Pepper‘s as the one most suited for a study of worldviews in science teaching. Still, the concept of worldview remains somewhat vague and ambiguous in these works (Cobern, 1989). It is also acknowledged that Pepper‘s six world hypotheses do not present a completely adequate way of classifying the range of worldview types people hold (Pepper, 1970; Proper et al., 1988). Furthermore, in the present study, the aim was to explore the contents of students‘ views of the natural world in-depth and to be able to conduct detailed comparisons between cases, rather than being limited to merely classifying individuals‘ worldviews according to one of six generalised types.

Kearney‘s (1984) logico-structure worldview model provides an analytic tool for studying worldviews at the individual level as well as for studying worldview variations (Cobern, 1989, 1996). His worldview model focuses the researcher‘s attention on the complexity of worldview, whilst the universal categories provide access to that richness and complexity (Cobern, 1989, 1994, 1996). Moreover, whereas Pepper‘s work is purely a theoretical piece, Cobern‘s studies (Cobern, 1991, 1993, 2000b; Cobern, Gibson, & Underwood, 1999)—based on Kearney‘s logico-structural model—provide empirical data from investigations of the worldviews of students (in college and in secondary school) and teachers. Indeed, Cobern‘s research closely matches the aim of the present study, that is, an investigation into the worldviews of Grade Six students, and his published work also includes detailed descriptions of procedures employed in collecting and analysing data. Therefore, this study draws upon the work of Cobern and Kearney in its conceptualisation of worldview theory. Kearney's logico-structural model of worldview is thus presented next, followed by a discussion of Cobern's studies of worldview within the context of science education.

Kearney's logico-structural model of worldview

Kearney (1984) considers worldview as a variant of the concept of culture which is a fundamental notion of American anthropology. According to Kearney (1984), the study of worldview is the description and analysis of the ways in which different people think about themselves, about their environments, space, time, and so forth. In short, a worldview is the set of images and assumptions that a person has about the world. There are two aspects of worldview, namely, content and structure (Kearney, 1984). The contents of people's worldviews may differ from one another, but the structure (i.e., the basic categories of thought) is universal. Universal structures of worldview include the notion of Self, Other, Relationship, Classification, Causality, Space, and Time (Figure 2.2). These are simply referred to as worldview universals. The universals enable cross-cultural comparisons of worldviews, as all people's worldviews consist of the same universal structure. Moreover, analysis of the contents of individuals' views pertaining to particular universals, raises awareness of intra-worldview variations (Cobern, 1989).

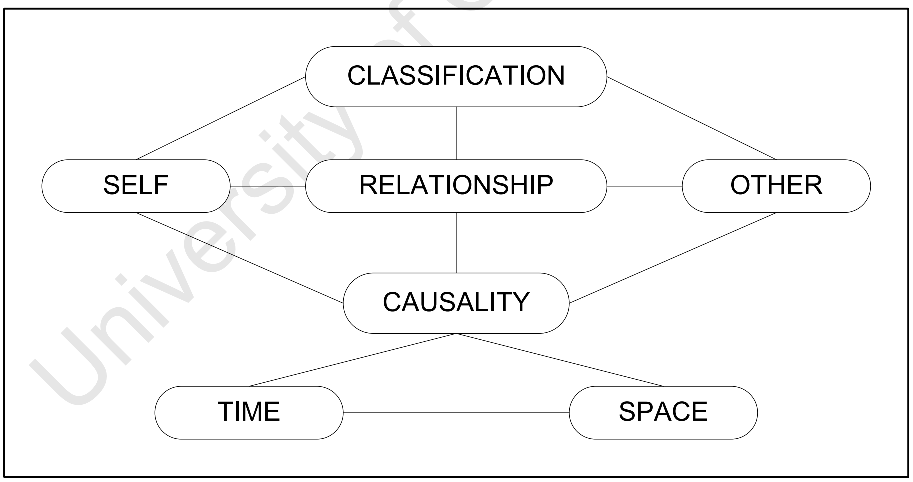


Figure 2.2: Dynamic interconnections between worldview universals (Kearney, 1984:119)

The first two worldview universals, the Self and the Other, form the backbone of a worldview. An individual's primary point of reference is her/himself (i.e., the Self), and yet every self exists and interacts within an environment (i.e., the Other or the NonSelf), where the NonSelf is everything other than the Self (Cobern, 1989). There are two aspects of the Self, namely, the awareness of Self as distinct from its surroundings, and the relationship between Self and its surroundings. Relationship is therefore the third worldview universal. Classification, the fourth universal, refers to the notion of ‗class‘, that is, the categories of reality that are recognised by people and the criteria by which they group the contents of these categories together (e.g., distinguishing between the Self and the NonSelf, or between what is real or unreal, or distinguishing between Nature and God). The fifth universal is Causality, which concerns relationships between causes and effects. People‘s views of Causality are dependent on the relationship between the Self and the NonSelf, and on their view of Space and Time (Cobern, 1989). These two are then the final two universals: Time and Space, and they include the ideas of constancy and change. Dynamic interconnections between universals (Figure 2.2) indicate how the contents of any one of the universals are related to all the others.

The contents of worldview, located within the universal structure, are referred to as images or assumptions. Kearney (1984) describes two types of images/assumptions. First-order assumptions exist at the core of every worldview as the contents of the universals. They are fundamental attitudes that are tacit knowledge, that is, they are normally not explicitly articulated, and they tend to be more abstract and therefore more elusive. Second-order images/assumptions are those that people readily describe (usually called beliefs/folk knowledge). Cobern (1989) refers to first- and second-order assumptions as *lived* worldview and *articulated* worldview, respectively. Elsewhere in the science education research literature, a distinction is sometimes made between personal knowledge (proximal knowledge) and declarative knowledge (distal knowledge), where the terms proximal and distal reflect distances from personal, lived experience (e.g., Hogan, 2000). Essentially, proximal knowledge comprises an individual‘s personal understandings and beliefs, whereas distal knowledge comprises knowledge and awareness which is not necessarily internalised by the student. The two types of knowledge (i.e., personal/proximal and declarative/distal knowledge) interact with one another (Hogan, 2000) and, in reality, the distinction between them is often obscured (Cobern, 1989). Nonetheless, the two types of knowledge are not necessarily the same for an individual (Hogan, 2000).

In addition to possible differences between first- and second-order images/assumptions within an individual‘s worldview, there exist differences in the worldview contents among people. ―Assumptions about reality vary considerably from one group to another, and at bottom they depend upon and affect the actual perception of it" (Kearney, 1984:41). Experience is the main force shaping the contents of worldview, and experience comprises two aspects, namely, environment and the nature of the mind itself. Differences amongst people‘s worldviews are explained by differences in environment, including culture and the subcultures of home, community, peers, school, and classroom, as well as people's individual ways of thinking (Ogunniyi et al., 1995; Thagard, 1994; Triandis, 1994). Indeed, the concepts of worldview, culture, and religion are closely related, in that particular worldviews result in certain patterns of action and not others, and therefore knowledge of a people's worldview should explain aspects of their cultural behaviour (the relationship between identity, culture, religion and worldview is discussed later).

> A worldview is not merely a philosophical by-product of each culture, like a shadow, but the very skeleton of concrete cognitive assumptions on which the flesh of customary behaviour is hung. Worldview, accordingly, may be expressed, more or less systematically, in cosmology, philosophy, ethics, religious ritual, scientific belief, and so on, but it is implicit in almost every act. (Kearney, 1984:52)

As previously explained (page 27), there is logico-structural inter-relatedness between the various images/assumptions of a person's worldview. Moreover, a worldview is a dynamic, more or less internally consistent system which demonstrates logical and structural regularities. More specifically, the organisation of worldview assumptions is shaped in two ways. First, by internal equilibrium dynamics among them, that is, some assumptions and the resultant ideas, beliefs, and actions, are logically and structurally more compatible than others, and the entire worldview will strive towards maximum logical and structural consistency. Second, equilibrium is maintained as a result of the need to relate to the external environment. That is, human social behaviour, social structure, institutions and customs are consistent with assumptions about the nature of the world (Kearney, 1984). Unfortunately, worldviews have never been entirely consistent. Two basic types of inconsistencies have been identified. External inconsistency occurs when the images of the worldview are inappropriate for the reality that the worldview presumably mirrors (e.g., the heliocentric image of the universe) (Kearney, 1984). External inconsistency also occurs when people with differing worldviews come into contact with one another (e.g., diverse classrooms in South African schools, and conflicting views of science as encountered at home and presented at school). Internal inconsistency arises from conflicting images/assumptions in the worldview itself (Kearney, 1984). In the present study, analyses of students' worldview contents and NOS view contents included an exploration of inconsistencies between individuals' NOS views and their worldviews, and of inconsistencies within each set of views (i.e., within their NOS views and within their worldviews). This is explained in detail in a later section (page 49).

In South African schools (DoE, 2002a; Hemson, 2006), external inconsistencies might occur due to the diversity of worldviews represented in the classroom. Moreover, some students' images of the world differ from that which is presented to them by the teacher. In the science classroom, conflicts might occur between students' views of science (i.e., their NOS views) and their views of the natural world, including that which is presented to them at school as opposed to at home. These potential worldview conflicts have important implications for NOS teaching and learning, as illustrated in the following extract from the South Africa's National Curriculum Statement (NCS):

> Different worldviews are usually present in the science classroom…[and]the existence of different worldviews is important for the Natural Sciences curriculum. One can assume that learners in the Natural Sciences Learning Area think in terms of more than one worldview. Several times a week they cross from the culture of home, over the border into the culture of science, and then back again. How does this fact influence their understanding of science and their progress in the Learning Area? Is it a hindrance to teaching or is it an opportunity for more meaningful learning and a curriculum which tries to understand both the culture of science and the cultures of home? (DoE, 2002a:11-12)

Students bring with them into the science classroom, ideas and values about the natural world that may or may not be compatible with science (Cobern, 1999). Accordingly, students' misconceptions might be a logical deduction from some fundamental view of Nature, rather than arising from a factual misunderstanding (e.g., due to students' uninformed naïveté or mis-instruction/mis-information). Students' worldviews might actively prevent them from developing a scientific understanding, or students might understand a scientific concept but their worldview does not esteem a scientific understanding. For other students, a proper scientific understanding might be possible, but science instruction might fail to connect new learning with students' existing worldviews (Cobern, 1989). The misconceptions referred to here can include not only students' ideas about particular scientific or natural phenomena, but also their understandings about the nature of science (NOS). Stated differently, worldview is likely to influence how students judge ideas that are presented to them regarding NOS. Developing informed views of NOS constitutes an important aspect of scientific literacy, which is a major goal in science education (Chapter 2, page 13). Thus, understanding the relationship between students' worldviews and their NOS views might aid us in identifying reasons why students' NOS views are typically naive, as well as helping to inform science teaching practices aimed at improving students' levels of understandings about NOS. Hence, the present study was designed to elicit students' ideas about the natural world (Nature) and explore how these relate to their views about the nature of science (NOS).

Worldview research in science education

Students' views and experiences of Nature are under-researched (Tunnicliffe & Reiss, 1999). In this regard, a significant contribution has been made by Cobern in his worldview studies in science education (N.G. Lederman, 2007) which draw upon Kearney's worldview model. More specifically, Cobern (1989) employs Redfield's (1952) tripartite division of the NonSelf into humanity (society), Nature, and God (the transcendent), and focuses on the subdivision of the NonSelf known as Nature, or the natural world (Cobern, 1993, 1999, 2000b). This is because Nature is the domain in which the natural sciences operate (Cobern, 1991, 1993). Cobern's studies aimed to investigate how the beliefs and experiences that students bring to the science classroom influence their experiences in the classroom. In support of Cobern's approach, Allen and Crawley (1998:126) write that "in science education, [a] key question is how one defines oneself in relation to Nature." Cobern's work is significant in that it represents a departure from other worldview studies that have been completed to date, as is explained below.

South African and African studies concerning worldviews have been conducted with science teachers (e.g., Ogunniyi et al., 1995), rather than school students. More importantly, these studies tend to focus on Indigenous Knowledge Systems or traditional knowledge (e.g., Dekkers & Mnisi, 2003; Jegede, 1991; Keane, 2008; Linneman et al., 2003; Le Grange, 2004; Malia & Loubser, 2003; Ogunniyi, 2004, 2005, 2007; Ogunniyi & Ogawa, 2008; Shumba, 1999; Webb et al., 2006). Indeed, a review of the science education literature concerning worldviews reveals that, rather than eliciting comprehensive data concerning students' views of what is nature, studies concerning students' views of the natural world seem to focus on eliciting broad definitions of what the natural environment is (e.g., Bonnett & Williams, 1998; Littledyke, 2004; Shepardson, 2005; Shepardson, Wee, Priddy & Harbor, 2007; Walker & Loughland, 2003), or reporting on students' attitudes towards the environment (e.g., Schultz et al., 2000; Tikka, Kuitenen & Tynys, 2000) and their environmental concerns (e.g., Littledyke, 2004; Walker & Loughland, 2003) and awareness and understandings of issues such as pollution and conservation (e.g., Bonnett & Williams, 1998; Tunnicliffe & Reiss, 1999; Walker & Loughland, 2003). These worldview studies are often located within the field of environmental education and therefore emphasise the relationship between people and nature, including a comparison of the views of students from different cultures (e.g., Schultz et al., 2000; Won, Paik & Cobern, 2009), and whether worldview differences, specifically in regard to indigenous cultures as opposed to a Western worldview, are a stumbling block for students learning science (e.g., Allen, 1995; Allen & Crawley, 1998; Chigeza, 2007; Dzama & Osborne, 1999; Emereole; Kawagley et al., 1998). Other studies have focussed on how students perceive and understand specific natural phenomena (e.g., Driver et al., 1994; George, 1999; O. Lee, 1999; Tsai, 2001; Tunnicliffe & Reiss, 1999). One exception to the particular foci of the above-mentioned studies, is found in a study in which the views of South Korean children in Grades Five and Six, regarding the natural world, were examined in relation to the Korean science curriculum (Won et al., 2009). This study involved a methodology employed by Cobern and his colleagues (Cobern, 1993; Cobern et al., 1999) in analysing Grade Nine students‵ conceptualisations of nature. Indeed, contrary to the worldview studies mentioned above, Cobern‵s work focuses on epistemological levels antecedent to specific concepts that students hold about physical phenomena (Cobern, 1989, 1994, 1996). Similarly, the focus of the present study is not on students‵ beliefs about particular natural phenomena (e.g., lightning, rainbows, diseases and natural disasters), but on students‵ epistemological, ontological, emotional and status descriptions of Nature that underlie such ideas.

In his worldview studies, Cobern investigated teachers‵ and students‵ conceptualisations of Nature and the extent to which they drew upon scientific knowledge in discussing Nature (Cobern, 1993, 2000b; Cobern et al., 1999). Individual‵s views of NOS were not explored. The present study aims to build on his work by focussing on the relationship between students‵ views of the natural world and their views of the nature of science (NOS). In order to explore this, this study of students‵ worldviews is grounded in Kearney‵s logico-structural model of worldview, with a focus on eliciting individuals‵ views of the natural world as a component of the universal worldview category ‗Other/Non-Self‵. Specifically, students were asked to describe their views concerning (i) knowing about the natural world (i.e., epistemological descriptions), (ii) what the natural world is like (i.e., ontological descriptions), (iii) how they feel about the natural world (i.e., emotional descriptions), and (iv) what the natural world is like now (i.e., status descriptions). Details regarding the specific data collection and analytical strategies are discussed in Chapter Three (page 53).

The natural world (i.e., Nature)

As explained above, the worldview component of the present study focusses specifically on eliciting and analysing students‵ views of the natural world. However, a review of the research literature concerning *What is Nature?* reveals this is a complex concept. Soper (1995), for example, describes Nature in terms of three concepts (i.e., metaphysical, realist and lay/surface concepts), whilst Weinert (2005) presents what might be considered a scientifically-inclined view of the natural world. In addition, Bonnet (2004:119) advises that ―our conceptions of Nature are not static and…they are numerous and heavily nuanced [however] it is possible to identify key themes in our understanding of the term ‗Nature‵". Soper‵s (1995) three concepts of Nature provide a useful starting point for a discussion of what Nature is, along with Bonnett‵s (2004) fundamental notions about Nature. Weinert‵s (2005) description of Nature is discussed thereafter.

The first concept of Nature described by Soper (1995) is a *metaphysical concept* of Nature which concerns humanity‘s relation to Nature, specifically, the distinction between humans and non-humans. In this regard, Bonnett (2004:122) describes Nature as ―self-arising" and independent of human purposes and culture. A metaphysical concept of Nature also concerns preserving Nature or making use of it in sustainable ways. The second concept is a *realist concept* of Nature, which concerns the physical structures, processes and causal powers that operate constantly within the natural world, and which are studied in science. These physical processes are observed as patterns and described in terms of laws (Soper, 1995). Related to this realist concept of Nature is the notion that everything in the natural world is interrelated (Bonnet, 2004). A realist concept also concerns the notion that people are always subject to the laws of Nature and that people cannot escape and neither determine nor destroy the physical processes in Nature (Bonnett, 2004, 2007; Soper, 1995). In this regard, Bonnet (2004:120) refers to ―the great scheme of things—the ‗natural order‘—of which everything is a part". This notion of natural order may be interpreted either in naturalistic terms (i.e., as a system of natural/physical laws and patterns of causality), or it can be interpreted religiously (i.e., in terms of divine purposes and revelations). However, the natural world comprises many things, and so Nature will never be fully witnessed or known (Bonnett, 2004, 2007). Related to the metaphysical concept about the sustainable use of natural resources, a realist concept of Nature concerns how the natural world is transformed by humans in, for example, the use of natural resources, waste, pollution and destruction (Soper, 1995). Soper‘s (1995) third concept of Nature is a *lay/surface concept*, which concerns features of the natural world that can be ordinarily, immediately and directly observed and experienced. This is the Nature of everyday experiences. A lay/surface concept of Nature also includes an aesthetic appreciation of Nature and people‘s feelings towards Nature (e.g., love/disdain, respect/indifference, expressions of sentiment referring to tranquillity and beauty) (Soper, 1995). Moreover, similar to the metaphysical and realist concepts of Nature, a lay/surface concept concerns that which we have destroyed and polluted and which needs to be conserved and preserved (Soper, 1995).

According to Weinert (2005), the concept of Nature has been created by human beings in an attempt to understand how the natural world functions—where the study of Nature is the objective of Natural science. Further to the above-mentioned three concepts of Nature, one might therefore consider what is a scientifically-inclined view of the natural world. In Weinert‘s (2005) overview of scientific discoveries that have had an impact on the fundamental concepts used to describe and explain the natural world, he describes the relationship between the nature of science, developments in scientific knowledge, and scientists‘ views of the natural world. As such, Weinert

(2005) presents what might be considered a modern/current view of Nature from the perspective of science. Discussions of the history of science (e.g., Barbour, 1997; Weinert, 2005) reveal how fundamental notions about Nature (i.e., time, space, causality) have evolved and changed, in response to significant scientific discoveries. A synopsis of Weinert‘s (2005) description is provided next, as a basis for expanding this current discussion on what Nature is.

An early *organismic view* of the universe described objects in terms of inherent tendencies, and events in Nature were explained in terms of the intrinsic characteristics of natural phenomena. Behaviour was understood in teleological terms, in that natural events were considered to occur in fulfillment of some overall Divine design in Nature. This untestable and metaphysical worldview was replaced by a *mechanistic worldview*, in which quantitative methods and mathematical language were employed to develop general principles and universals about Nature, based on sensory experiences/observations and scientists‘ reasoning (i.e., empirical study). The mechanistic worldview described Nature as being deterministic, that is, observable properties were related to an underlying causal structure which determined the behaviour of its various constituent parts. In contrast to the organismic worldview, physical objects were not regarded as having natural tendencies or essential natures. Changes happened according to rules and were therefore explained by mechanical causes as opposed to teleological purposes. This said, however, God was thought to have set the universe in motion. Thereafter, either the natural world continued to function with perfect regularity and thus no further attention was needed (Deism), or the occasional divine adjustment was needed to keep its regularity (Theism). Following this mechanistic worldview, a *dynamic view* of the natural world began to emerge, in which Nature was no longer considered merely as a dead aggregate of matter. Some scientists described Nature either in terms of _being‘ (i.e., fundamental reality was said to be _timeless‘, and the passage of time was a human illusion) or _becoming‘ (i.e., the material world was considered to be in constant flux, hence there was no physical time). The philosophy of ―becoming” was regarded by some as being compatible with the theory of relativity that emerged as part of the modern worldview. The dynamic view of Nature also included the idea of mutual causation in that things result from joint actions of forces in the cosmos. A systems view of Nature is what has now emerged as part of a modern view of the natural world.

The *modern view* of Nature is that of a system of interrelated systems: not only are all the elements within a single life form connected, but there exists also a vast system of all the various subsystems in Nature (e.g., a galaxy consists of planetary systems, which consist of planets and the laws which hold them in orbit). There is order in Nature, and therefore knowledge of some parts enables knowledge of other parts. Everything is related by mechanical laws. There exists a cause-effect relation which is subject to the laws of Nature, although the causal link is not necessarily observable. Natural events are not completely random, but they are not uniquely predictable, and so in this sense, the previously held notion of determinism has been replaced by the notion of indeterminism with probabilistic causation. Two types of causal links are thought to exist, namely, an absolutely necessary link and a merely probabilistic link. Behaviour appears to be deterministic in the macro-world, whereas in the micro-world, behaviour is apparently indeterministic. Also, the natural world is discontinuous in that some things happen in quantum jumps.

The above historical synopsis includes epistemological descriptions of the natural world that are both *knowable* (e.g., regarding order in Nature, including, for example, that physical objects are governed by mechanical laws, and that causal links exist between apparently random events in Nature) and *unknowable* (e.g., that some events in Nature seem unpredictable and unexplainable). Ontological descriptions include views of Nature that are both *super-naturalistic* (e.g., the possibility that God created Nature) and *naturalistic* (e.g., that physical objects do not have natural tendencies, and that natural phenomena do not occur in fulfillment of a greater overall purpose in Nature). In addition, it could be argued that emotional responses of Nature include both *positive* views (e.g., relating to a curiosity to study and learn more about Nature) and descriptions of *negative* aspects of Nature (e.g., concerning the danger and destruction associated with natural disasters). Status descriptions of Nature include views that are both *conservationist* (e.g., concerning the conservation of resources, and views that Nature is pure/undamaged when untouched by people and should be preserved for its intrinsic worth [Bonnett, 2004; Soper, 1995]) and *resource-oriented* (e.g., utilitarian views of Nature, and the notion that human technological capacity enables mastery over Nature [Bonnett, 2004; Soper, 1995]). Furthermore, individuals' views of the macro-world may differ from their views of the micro-world. As such, as was pointed out at the beginning of this discussion about what the natural world is (page 32), Nature is a complex concept.

Views of the natural world constitute one component of worldview (page 30). The current review of the relevant research literature now returns to a discussion relating to the broader construct of worldview (of which views of Nature form a part). The relationship between culture, religion, identity and worldview is presented next.

Culture, Religion, Identity and Worldview

Worldview is impacted by a number of factors, and one of these factors is culture (Cobern, 1994, 1998, Ogunniyi et al., 1995; Thagard, 1994). Culture imposes a set of lenses for seeing the world, and culture influences the way in which humans select, interpret, process and use information (Triandis, 1994). Culture therefore impacts on learning. Indeed, science learning is sometimes depicted as a cross-cultural activity (Aikenhead, 2006; Cobern, 1994, 1998; Ogawa, 1995). A short discussion of culture therefore needs to be included in explaining the conceptual framework of the present study.

Culture is a complex concept, and hence a number of definitions of culture exist (Triandis, 1994). Triandis (1994), who has published a number of important works on cross-cultural research, favours the definition of culture as ―the human-made part of the environment", which he differentiates as objective and subjective culture. According to him (Triandis, 1994) when we analyse subjective culture (i.e., norms and values) we learn how people perceive, categorise, believe, and value entities in their environment—that is, their worldview. A number of criteria are applied in discriminating one culture from another. In particular, differences amongst people include characteristics such as age, gender, language, nationality, religion, and social class. Most researchers recognize these characteristics as aspects of culture (Triandis, 1994), and they are therefore the main factors pertaining to cultural diversity (and, in particular, worldview diversity) that were considered in the present study. Although there are similarities between people, differences also exist between them, and these differences can be culture-specific. Indeed, according to Kearney‘s (1984) worldview theory, culture influences the differences that arise amongst the contents of the universal structures of people‘s worldviews (such as, for example, people‘s beliefs about themselves and about the relationship between themselves and their environment, their understanding of cause-effect relationships, and their ideas about time [page 27]). Moreover, in comparing cultures it has been noted that, throughout the world, religion governs the life of most people, although the extent to which this is true varies from culture to culture (Triandis, 1994). The constructs of worldview and religion are therefore closely related, and these two constructs hold close ties with the concept of culture. Figure 2.3 illustrates how the concepts of culture, religion (and identity, as discussed next [page 36]), and worldview—as used in this study—are related.

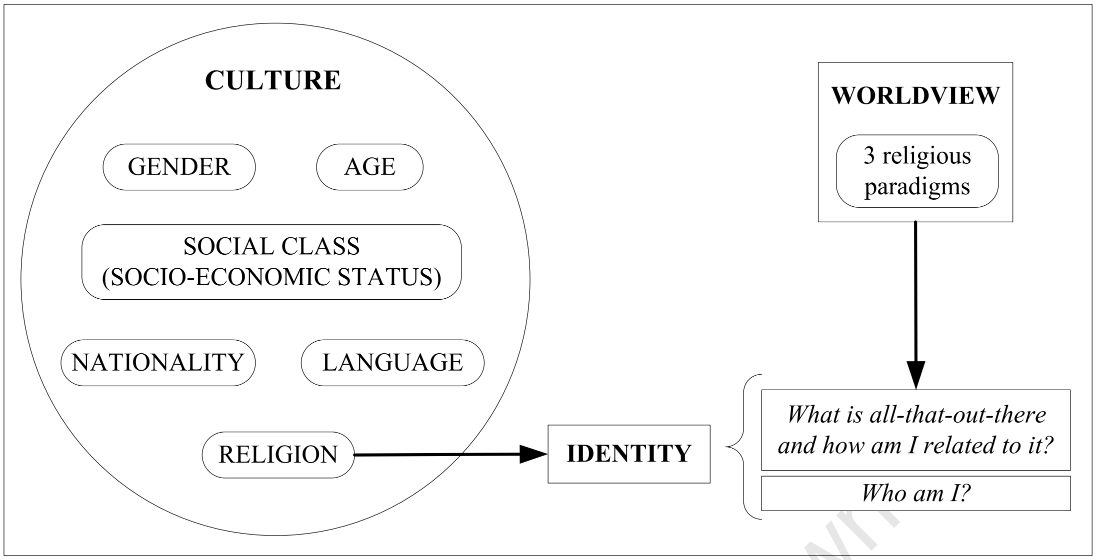


Figure 2.3: Relationship between aspects of culture (including religion) and worldview in describing similarities and differences amongst people

Religion plays an important role in shaping individuals, specifically in determining their view of reality (or worldview) (Cobern, 2000a; De Wet, 2000; Prozesky, 1991). This is because religion is about the basic human drive to answer the question, *What is all-that-out-there and how am I related to it?* (Cumpsty, 1991). Related to this first question is a second question, namely, *Who am I?* (Cumpsty, 1991). Notably, these two questions are directly concerned with the principle worldview universals of the Self, NonSelf, and Relationship in Kearney‘s (1984) logico-structural worldview model (page 27). In addition, the second question, which is argued to be the longest lasting and most significant question in life, speaks to the drive for identity (Cumpsty, 1991).

As such, religion forms part of one‘s identity as a human being (Prozesky, 1991). In fact, identity is considered by some to be an essential part of religion (Cumpsty, 1991). By implication, therefore, identity is also an important component of worldview, and of culture. Indeed, students‘ perceptions of the relevance of what they learn at school concerns the relationship between curriculum content and classroom experiences on the one hand, and students‘ cultural self-identities on the other (Aikenhead, 2006).

There are myriad forms of identity, however, possible answers to the question *What is all-that-out-there…?* are not unlimited. Cumpsty (1991) writes that there are only three approaches (or paradigms) to interpreting the *world-out-there*, namely, the Take-Hold-and-Shape paradigm, the Fit-Into-the-Natural-Order paradigm, and the Withdrawal paradigm. A synopsis of some of the key features of each of these paradigms is provided in Table 2.1. In the South African context, the

Abrahamic family of faiths (i.e., Judaism, Christianity, and Islam) most closely fit the first religious paradigm, whilst Traditional African worldviews reflect the second (De Wet, 2000). Although, in practice, people's worldviews and traditions often incorporate elements of more than one paradigm, and people re-negotiate their worldviews and identities in response to changing socio-cultural experiences, there are many situations in which a single paradigm predominates (Cumpsty, 1991; De Wet, 2000).

Table 2.1: Synopsis of some key features distinguishing the three religious paradigms, namely, Take-Hold-and-Shape, Fit-into-the-Natural-Order, and Withdrawal (Cumpsty, 1991; De Wet, 2000)

	Take-Hold-and-Shape	**Fit-into-the-Natural-Order**	**Withdrawal**
Examples of religions associated with the paradigm	Abrahamic family of religions (i.e., Judaism, Christianity, Islam)	Traditional African religions	Religions originating in India (e.g., Buddhism, Hinduism)
View of reality (i.e., monistic or dualistic)	Dualistic reality (i.e., the Creator [divine, personal] is separated from the Created [secular])	Monistic reality (i.e., religion is not separated from life in general)	Monistic reality
View of people's relationship to the world-out-there	People actively take hold of their immediate (secular) environment, and shape it in conformity with the divine will.	People aim to maintain harmony with others and with the natural order.	Withdrawal from the world-out-there - the immediate environment is transient and deceptive.
Focus of religious traditions (i.e., individual or communal)	Religious tradition is focussed on the individual.	Religious tradition is focussed on the communal.	Religious tradition is focussed on the individual and the universal (i.e., all beings share the same task, that is, the discovering a path to realisation).
View of time and the After-life	Time is linear: After death, people go to Heaven.	Time is cyclical: After death, people join the ancestors.	Time is cyclical: After death, people are reincarnated

Students in most classrooms have subtle worldview variations, and these variations are an important factor in their science learning (Cobern, 1989). Indeed, the children in South African classrooms represent a diversity of cultures (DoE, 2002a; van Wyk, 2002). Therefore, in exploring the coherence of students' NOS views and their worldviews, there existed a need to maximize the diversity of worldviews represented by the students being studied. Religion is an important cultural marker as well as an important component of worldview, and it plays an essential role in the generation and securing of an individual's identity. Thus, this study drew upon Cumpsty's (1991) description of three religious paradigms in order to purposefully select individuals from diverse religious/cultural backgrounds, and by implication, with diverse worldviews. Further details

regarding the selection of the participants for this study are provided in Chapter Three (page 57).
In addition to cultural and worldview differences amongst individuals, many students experience learning in science as a cross-cultural event. The notion of cultural border-crossing in science education is discussed next.

Cross-cultural learning in science: Border-crossing

A discussion of border-crossing in science education can be approached from two perspectives: a discussion of the notion of sub-cultures and moving between various sub-cultures, and a distinction between non-school knowledge (e.g., everyday knowledge that which is learned at home, and/or from peers and members of the local community) and educational knowledge (i.e., scientific knowledge that is presented to students at school). However, common to both frames is the notion of students negotiating cultural borders when learning science. Different types of transitions can be identified, as well as various strategies for coping with such border-crossings.

Values, beliefs, worldviews, and views of nature are attributes of culture (Aikenhead, 1996; Cobern, 1994, 1998, Ogunniyi et al., 1995; Thagard, 1994, Triandis, 1994). What is more, at any given time, individuals belong to several sub-groups within their culture (sub-cultures) (Aikenhead, 1996). In science education, the most significant sub-cultures influencing students' understandings are the family, peer groups, classroom, and the school. These are components of a student's life-world (Aikenhead, 1996; Jegede, 1995). In addition to life-worlds, science could also be considered a culture, as it comprises shared norms, values, beliefs, and so forth (Aikenhead, 1996; Jegede, 1997). Moreover, modern science can be regarded as a sub-culture of Western/Euro-American culture (Aikenhead, 1996). School science is closely aligned with sub-culture science, and in school science, students are expected to acquire the norms, values, beliefs and so forth, of science, and to make them part of their own personal worlds. Along similar lines, Ogawa (1995) argues for a *multiscience* perspective for science education, in which he differentiates between personal science, indigenous science and modern Western science. According to him (Ogawa, 1995), individuals have a personal science, that is, their rational perception of reality. In addition, every culture has an indigenous science, which is transferred to its members by daily social and cultural events. These two sciences pertain to the students' everyday life-world. At school, students are then presented with modern Western science, which is a theoretical construct and one of many different ways of describing and interpreting natural phenomena. However, this science is typically foreign to students—albeit non-Western or indigenous, and Western students—and it interferes with students' traditional cultures and/or with their commonsense understandings of the world

(Aikenhead, 1996; Cobern, 1999; Odhiambo, 1972). Therefore, for many students, science learning can be regarded as a cross-cultural event, as they move between the sub-cultures of their life-world (family, peer groups, etc.) and the sub-culture of science (Aikenhead, 1996, 2006; Cobern, 1994, 1998; Ogawa, 1995).

Further to the theoretical frame of science as a sub-culture, and science learning being a cross-cultural experience for many students, a distinction can be made between non-school knowledge learned at home (everyday concepts) and educational knowledge (scientific concepts) transmitted in school (Bernstein, 1975; Cobern, 1998; Vygotsky, 1962). On the one hand, non-school knowledge is rooted in students‘ ordinary, concrete, personal experiences. Everyday concepts are spontaneous and commonsense. In contrast, educational knowledge results from formal, classroom instruction and it is abstract and esoteric. The scientific concepts associated with educational knowledge are systematic and ‗uncommonsense'. At school, therefore, children are typically presented with concepts that are vastly different to the knowledge they bring with them from home. Furthermore, whereas non-school knowledge is community-based, educational knowledge has a sacred status and it is associated with a sense of otherness. There might also be different meanings attached to the language used in science that perhaps does not correspond to commonsense/everyday language use (Aikenhead, 1996; M.G. Hewson, 1988). Accordingly, symbolic continuity (extension) or discontinuity (disturbance) might exist between home and school, depending on the strength of the classification (boundaries between school subjects and teachers) and framing (control over the selection, sequencing and pacing of knowledge to be acquired) of the curriculum. The strength of the classification and framing determines whether the culture of the family and community, and the experiences of the child, are legitimised or rejected in the classroom. As such, formal transmission of educational knowledge can be viewed as a cultural transmission, and school learning can transform the identities of many children (Bernstein, 1975).

School science can therefore be regarded as a sub-culture distinct from students‘ life-world sub-cultures, or it can be described within the frame of educational knowledge (and scientific concepts) being distinct from non-school knowledge (everyday concepts). Nonetheless, common to both frames is the notion of students crossing borders when learning science at school. Four types of transitions are suggested as a means of describing how students move between their life-world sub-cultures and science as a sub-culture, or between non-school knowledge and educational knowledge (Aikenhead, 1996; Phelan, Davidson, & Cao, 1991). The various transitions are typified according to the degree of congruency or continuity between the sub-cultures that a student is moving between, as well as the ease with which a student negotiates the transitions. The four transition types can be presented in a continuum (Table 2.2). On the one end of the continuum, where there is a high degree of discontinuity between sub-cultures (or knowledge types), the boundaries between them seem ‗impossible‘ for students to cross. On the opposite end of the continuum, students experience ‗smooth‘ and harmonious border-crossings, where sub-cultures (or knowledge types) are congruent with one another. In between these two extremes, border-crossings are ‗hazardous‘ and only possible under certain circumstances, where sub-cultures are diverse and distinct, and therefore transitions between them involve friction and unease. Border-crossings are ‗managed‘ when students perceive some differences between sub-cultures, yet individuals are able to move between sub-cultures by adapting to different settings as needed (Aikenhead, 1996; Phelan et al., 1991).

Success in school science is influenced by the degree of difference that students perceive between their life-world and their science classroom, and the ease with which students negotiate such border-crossings (Jegede & Aikenhead, 1999). Therefore it is important to understand students‘ multiple worlds (i.e., the different contexts in which students operate) and their border-crossing behaviour (Phelan et al., 1991). Students employ different strategies in dealing with discordance. One such strategy involves playing ―Fatima‘s rules”, whereby students can pass a course without understanding the content (Aikenhead, 2006:28; Jegede & Aikenhead, 1999:18). A second strategy involves students rejecting or ignoring a discordant view (Tsai, 2001). A third set of strategies concern various types of collateral learning, where students practise ―cognitive apartheid” (Jegede & Aikenhead, 1999:13) in various degrees, that is, students isolate and segregate school science content within their minds, or they compartmentalise scientific understandings from their everyday lives (Cobern, 1999). Collateral learning, in particular, has received attention within the science education literature relating to border-crossing issues, and therefore it warrants a brief overview here.

In short, collateral learning theory describes the cognitive experience of how students hold two or more conflicting schema simultaneously in their long-term memory (Aikenhead & Jegede, 1999; Jegede, 1995, 1997). There are variations in degrees of interaction between conflicting ideas and variations in the degree to which conflicts are resolved, and these can be represented on a continuum (Figure 2.4). Teachers can guide students to progress along the continuum in helping them to make sense of discordances. That is, rather than students compartmentalising their ideas

Table 2.2: Types of transitions (border-crossings) experienced by students when learning school science (Aikenhead, 1996; Phelan et al., 1991)

	Discontinuity between sub-cultures / knowledge ⟵			⟶ Continuity between sub-cultures / knowledge
	TYPE OF TRANSITION			
FEATURES OF TRANSITION TYPES	**Impossible**	**Hazardous**	**Managed**	**Smooth**
Degree of congruency/continuity between sub-cultures	Highly discordant	Diverse and Distinct	Different	Congruent
Student's perceptions of the boundaries	Boundaries seem insurmountable and rigid, impenetrable and constraining.	Border-crossing is only possible under certain conditions.	Perceptions of boundaries do not prevent student from managing crossings or adapting to different settings.	Boundaries are barely perceived; Commonalities override differences.
Student's experience of the transition	Painful, therefore border-crossing is resisted.	Requires adjustment and re-orientation when moving between; Involves friction and Unease.	Requires adjustment and re-orientation when moving between sub-cultures; Not always easy; Sometimes involves personal and psychic pain.	Harmonious, uncomplicated.
Student's success in learning school science	Less successful academically	Less successful academically	Academically successful	Academically successful

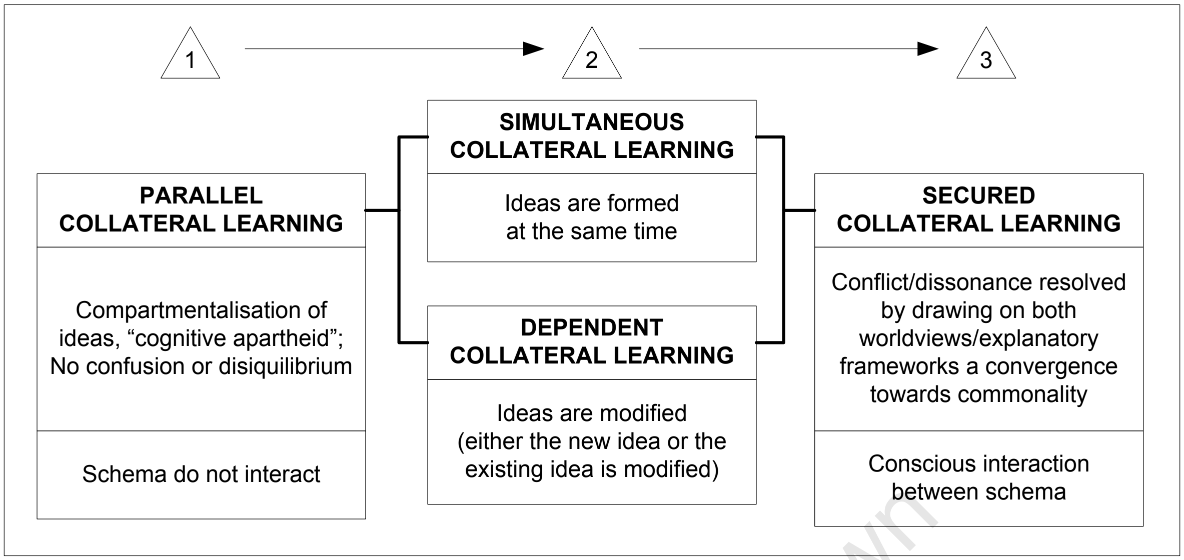


Figure 2.4: Diagrammatic representation of students' various cognitive experiences to explain border-crossings (collateral learning theory) (Jegede, 1995; Jegede & Aikenhead, 1999)

and keeping schema separated (i.e., parallel collateral learning), alternative explanations can be learned simultaneously by students (i.e., simultaneous collateral learning) and ideas (albeit new or existing) can be modified in relation to one another (i.e., dependent collateral learning), and ultimately, students can resolve worldview conflicts by simultaneously drawing upon various explanatory frameworks (i.e., secured collateral learning) (Jegede, 1995; Jegede & Aikenhead, 1999).

Notions of border-crossing and collateral learning in science education, as outlined above, draw attention to the possibility that students can experience differences—and conflicts—between science and their personal worldviews. Indeed, the relationship between science and various worldviews, for example, religious worldviews, is ―one of the most significant and yet unsettled aspects of science" (Gauch, 2009:668), and ―constitutes a significant chapter in the history of science and humans' cultural heritage" (Staver, 2010: 20). Moreover, the purported conflict between science and religion relates not only to the physical sciences but also to the life sciences (Loo, 2001). An example of a specific area of conflict concerns views of creationism as opposed to evolution (e.g., Edis, 2009; Loo, 2001; Mahner & Bunge, 1996).

A principal topic of debate seems to concern whether, or to what extent, religious views and science views are compatible or incompatible (e.g., Clements, 1990; Edis, 2009; Guessoum, 2010; Hansson & Redfors, 2007a; Irzik & Nola, 2009; Loo, 2001; Mahner & Bunge, 1996; Mansour, 2010; Poole, 1996; Reiss, 2010; Roth & Alexander, 1997; Staver, 2010; Upadhyay, 2010;

Woolnough, 1996)—where ‗compatibility‘ refers to the ability to exist together or to be used together without problems or conflict (Kavanagh, 2007). It is beyond the scope of the present study to engage extensively with the debate concerning the in/compatibility of science and religion. However, one aspect that warrants further mention here, concerns the dialogue about different ways in which people perceive and manage the relationship between science and religion (e.g., Barbour, 1997; Haught, 1995). As will be argued later (page 46), in the present study, there existed the possibility that the Grade Six students might articulate varying degrees of discontinuity in describing their views of NOS and their views of the natural world (a component of worldview), and that their descriptions might include examples of particular worldview conflicts.

The possible categories of interaction between science and religion, which form part of the science-religion-in/compatibility debate, bear some similarities to the notions of cultural border-crossing presented earlier (page 40), with regard to the degrees of difference that can exist between alternative explanatory frameworks (Table 2.3). That is, where worldviews (e.g., science and religion) are highly discordant, and students experience conflicts between explanations offered by science and religion, students experience border-crossings that are ‗impossible‘. Where worldviews are distinct and remain separate within the student‘s conceptual framework, border-crossing experiences are ‗hazardous‘. However, border-crossings are ‗managed‘ by students when there is some form of interaction between different worldviews. Border-crossings are ‗smooth‘ when worldviews are mutually supportive of, and integrated with, one another (Aikenhead, 1996; Barbour, 1997; Haught, 1995; Phelan et al., 1991).

Further to the above, in the research literature concerning the relationship between science and religion, various possible resolutions to worldview conflicts are proposed (e.g., Staver, 2010). Jegede‘s theory of collateral learning, as previously outlined (page 41), also concerns strategies for dealing with discordant worldviews (which are represented as a continuum) (Figure 2.4). Therefore, Staver‘s (2010) possible resolutions to worldview conflicts can be compared with Jegede‘s (Aikenhead & Jegede, 1999; Jegede, 1995, 1997; Jegede & Aikenhead, 1999) collateral learning theory—by presenting the former as a continuum (Figure 2.5). According to Staver (2010), students might perceive science and religion as being incompatible and therefore choose one worldview to dominate over the other, or students might hold alternative explanations separately within their conceptual frameworks, or students might resolve conflicts between science and religion by recognising how the two different knowledge frameworks interact with one another.

Table 2.3: Synopsis of a comparison between four categories of interaction between science and religion (Barbour, 1997; Haught, 1995), and four types of border-crossing in science education (Aikenhead, 1996; Phelan et al., 1991)

CRITERIA OF COMPARISON	**Discontinuity between sub-cultures / knowledge** ⟵	⟶		**Continuity between sub-cultures / knowledge**
Types of border-crossing	Impossible	Hazardous	Managed	Smooth
Interaction between science and religion	Conflict	Contrast/ Independence	Contact/ Dialogue	Confirmation/ Integration
Areas of congruency between the two classification frameworks	Worldviews are highly discordant and reconciliation is impossible.	Worldviews are diverse and distinct. Worldviews are independent ways of understanding reality, and although there might not be explicit conflict, they are kept separate from one another (compartmentalisation).	Worldviews are different, yet there is potential for dialogue and mutual impact. Differences do not prevent the student from moving across boundaries or adapting to different settings.	Alternative worldviews positively support each other. Interaction between worldviews is harmonious.

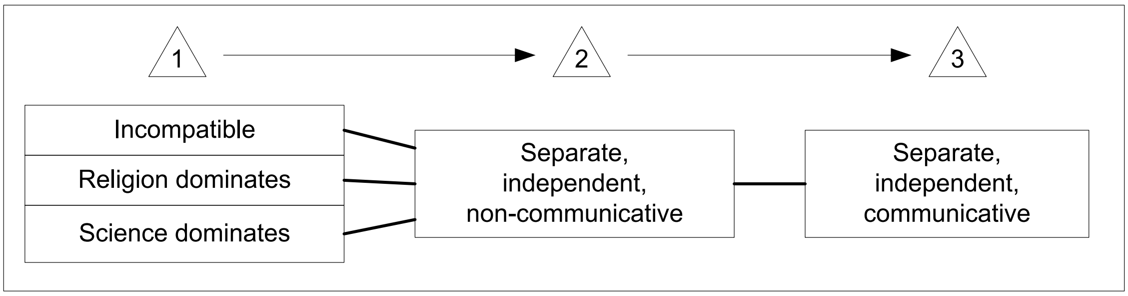


Figure 2.5: Staver's (2010) resolutions of conflicts between science and religion, depicted as a continuum

A comparison of the theories of Staver and Jegede reveals an important difference between them. According to collateral learning theory, teachers are encouraged to guide students towards resolving worldview conflicts by drawing on multiple explanatory frameworks and establishing points of commonality between them (i.e., secured collateral learning), including the possibility of modifying one set of ideas in order to accommodate another (i.e., dependent collateral learning). In contrast, according to Staver's (2010) proposed resolutions to worldview conflicts, different explanatory frameworks exist independently and remain separate from one another. Clearly, further research is needed in order to unpack the relationship between collateral learning strategies, possible resolutions to worldview conflicts, various categories of interaction between science and religious worldviews, and the range of border-crossing types—and how a theoretical framework incorporating these various ideas might be related to an increased understanding of students' levels of NOS understandings.

In summary, in science education, the notion of border-crossing concerns students negotiating differences in how natural phenomena are explained to them. That is, there might be differences between students' commonsense, everyday understandings and the educational knowledge presented to them at school, or there might be differences between students' personal worldviews (e.g., religious beliefs) and the worldview conveyed by science. The in/compatibility of different worldviews (e.g., differences between science and religion) remains an issue of some debate. Nonetheless, various resolutions to worldview conflicts have been suggested, some of which emphasise differences (i.e., Staver, 2010) whilst others work towards the convergence of alternative explanatory frameworks (i.e., collateral learning theory). According to the latter, it seems possible for students to hold different views of the world simultaneously (Jegede, 1995), however worldview remains a possible barrier in learning science (Lynch, 1998; M.G. Hewson, 1988; Hodson, 2009; Jegede & Aikenhead, 1999).

Of particular relevance for the present study is the possibility that varying degrees of congruency or discordance might exist between students' views of the natural world and their understandings of science (NOS). If one considers that, during the process of learning, individuals strive towards consistency or coherence within their views of reality, then it can be said that teaching strategies will only be effective if students can relate what is presented to them in science (and about science) to their own existing worldviews (Waldrip & Taylor, 1999). What follows next is a discussion concerning conceptual change and a coherence view of learning.

Conceptual change and a coherence view of learning

According to conceptual change theorists, learning entails more than the acquisition of a desired set of behaviors and responses: meaningful learning involves students relating new ideas being taught to a pre-existing cognitive framework of concepts and understanding in their minds (Ausubel, 1967, 1968; Carey, 1986; Cobern, 1994; P.W. Hewson, 1982; M.G. Hewson, 1988; O. Lee, 1999; Posner et al., 1982). Students‘ existing conceptual frameworks are the result of all previous learning (Ausubel, 1967, 1968; Vosniadou & Ionnides, 1998) and it is by means of these cognitive structures that students organize their knowledge of the world (Ogunniyi et al., 1995; Robson, 2006). Students‘ conceptual frameworks serve to control the process of learning by determining which new concepts are retained or rejected, depending on how the new ideas relate to students‘ current thinking (Ausubel, 1967, 1968; P.W. Hewson, 1982; Posner et al., 1982). A person‘s existing knowledge therefore plays a critical role in her/his learning in science. This idea is encapsulated in Ausubel‘s (1968: vi) well-known statement: ―The most important single factor influencing learning is what the [student] already knows. Ascertain this and teach him accordingly.” Indeed, it is suggested that the main barrier to learning is not the knowledge which the students lack, but rather the understandings that they currently hold (Carey, 2000). Accordingly, people resist acquiring scientific information when it conflicts with their existing views about the world (P. Bloom & Weisberg, 2007).

Students‘ metaphysical commitments (i.e., beliefs and views about what the world is like) play a very significant role in the way that they understand complex science subject matter (Carey, 2000; Cobern, 1994; P.W. Hewson, 1982; Posner et al., 1982), and form the basis from which judgments are made about new knowledge. Students‘ metaphysical beliefs about the world constitute part of their worldview (Kearney, 1984). Indeed, the concept of worldview is closely related to that of a conceptual framework (Cobern, 1994; Kawagley et al., 1998) in regard to ordering the contents of a person‘s knowledge structures. Students bring with them into the science classroom—based on their everyday experiences—a diverse range of worldviews (Brown & Abell, 2007), and these are typically different to the worldviews of their teachers as well as being different to the worldview presented to them in science (Carey, 1986; Cobern, 1994; Treagust & Duit, 2008; Vosniadou & Ionnides, 1998). The presence of various student worldviews in the classroom has implications for meaningful learning in science. In order for meaningful learning to take place in science classrooms, the science concepts being taught need to be related to the students‘ existing conceptualisations (Cobern, 1994; P.W. Hewson, 1982, M.G. Hewson & Hewson, 1989; Jegede, 1995; Posner et al., 1982)—this is a coherence view of knowledge. Indeed, it can be considered that ―students are not scientifically literate until the conceptual knowledge they have of science is meaningfully integrated into a cognitive framework that includes their everyday thinking" (Cobern et al., 1999:558).

Drawing upon a coherence view of knowledge, a theory of explanatory coherence was developed by Thagard (1989, 1994) to analyse conceptual change in students‘ minds. In particular, explanatory coherence theory was devised in order to determine how individuals accept or reject a new concept depending on the extent to which the new concept coheres with their other, pre-existing beliefs and understandings (i.e., conceptual framework). As such, explanatory coherence theory is based on the premise that the acquisition of knowledge in students involves an important restructuring of their conceptual frameworks (conceptual change) as opposed to being simply a matter of accumulating new facts (knowledge enrichment) (Thagard, 1992). Within the field of science education, explanatory coherence theory has been used in philosophical discussions about conceptual change (e.g., diDessa & Sherin, 1998; Taber, 2001; Thagard, 1992; Treagust & Duit, 2008), and has been applied in empirical studies that focus on, for example, analyzing changes in students‘ understanding of basic physics concepts (e.g., the motion of projectiles) (Ranney & Thagard, 1988), comparing the conceptual frameworks of teachers and students regarding electrostatics (Koponen & Pehkonen, 2010), and exploring students‘ explanations of evolution (Kampourakis & Zogza, 2009). Such studies have focused on conceptual change in relation to students being taught particular science subject-matter (Carey, 2000; Carey & Spelke, 1996; Posner et al., 1982). However, the notion of conceptual change can also be applied to students‘ concepts about science as an endeavor, that is, their knowledge and understanding about the nature of science. The notion of conceptual change can also be applied in studying students‘ conceptualisations of Nature (i.e., their views relating to the natural environment, a component of one of the universal worldview structures [Non-Self]). Accordingly, in the present study, explanatory coherence theory is explored as a potentially useful tool for analyzing the relationship between students‘ views of NOS and their views of the natural world.

Explanatory Coherence Theory

Explanatory coherence concerns the relations between various concepts and ideas that exist within a student‘s conceptual framework, including the connection between two single concepts, and the relation between a single concept and a larger set of concepts (Thagard, 1989, 1994). Coherence means ―holding together” (Thagard, 1989:436), and the extent to which ideas or concepts hold together is due to explanatory relations. In other words, relations between concepts are revealed by means of students‘ explanations of what they know. For example, concept A could form part of an explanation of concept B, or concepts A and B could both form part of the explanation of C. When ideas/concepts agree with one another they *cohere*, and they *incohere* when they conflict with one another or if they offer incompatible explanations of the same phenomenon (Thagard, 1989). Links can therefore be established where the explanations of certain concepts in different contexts are similar or contradictory. Such links between concepts are determined by applying principles of explanatory coherence.

Explanatory coherence principles therefore provide a useful means for describing the relationship between particular concepts, as well as for describing the overall coherence of a student‘s conceptual framework. Specifically, the application of coherence principles enables the researcher to identify instances where, for example, concepts agree with each other equally (symmetry) or contradict one another (contradiction), and where there is agreement (explanation) or conflict (competition) between a concept that is being explained and an example that is cited, and also where there is agreement or conflict between a concept and the larger conceptual framework of which it forms a part (system coherence/system incoherence) (Thagard, 1989, 2006). The present study explored the application of these explanatory coherence principles in analyzing the relationship between students‘ views of NOS and their views of the natural world in a detailed and nuanced manner. Moreover, this approach constitutes a novel methodology for studying this little-known relationship.

The relationship between worldviews and NOS views has been identified as an area of much-needed research (N.G. Lederman, 2007) (page 19). Indeed, this area of research has been addressed by only a few studies. Notably, however, none of these studies provide detailed insight into the relationship between views of the natural world and views of NOS. Some of them (e.g., Liu & Lederman, 2002, 2007; Sutherland & Dennick, 2002) simply raised more questions about the relationship between NOS and worldview, whilst others did not record respondents‘ NOS views (e.g., Kozoll & Osborne, 2006; O. Lee, 1999; Littledyke, 2004), and still others had a limited worldview focus (e.g., O. Lee, 1999, D.D. Lee, 2003). To begin with, Sutherland and Dennick‘s (2002) study concerning the NOS views of Cree (i.e., First American) and Euro-Canadian Grade Seven students reported results that were unreliable and which do not reveal much about the relationship between the contents of individuals‘ worldviews and their NOS views (page 20). Liu and Lederman (2002, 2007) conducted two studies concerning worldviews and NOS views. Their studies involving Grade Seven Taiwanese students (Liu & Lederman, 2002) and Taiwanese pre-service elementary teachers

(Liu & Lederman, 2007) highlighted the need for further exploration of the relationship between worldview and NOS.

In his doctoral study, D.D. Lee (2003) examined the views held by religious ministers and pre-service teachers concerning the relationship between science and faith, and how these views correlated with participants‘ understandings of controversial science concepts (e.g., biological evolution, geological history) and their understandings of NOS. The relationship between science and faith is a component of worldview. However, rather than eliciting respondents‘ underlying views of the natural world (e.g., epistemological and ontological descriptions), the study focussed on the ministers‘ and teachers‘ content knowledge about two particular topics, and on how their views of science and religion influence each other. Furthermore, in examining the participants‘ NOS views, the researcher focussed only on limited aspects of NOS (i.e., definition of science, limitations of science, the role of theories and laws, and the role of evidence).

Further to these four studies is one conducted by Littledyke (2004), who investigated elementary school students‘ perceptions of science in relation to environmental issues. However, the focus of Littledyke‘s study was on the connection (or lack thereof) between students‘ views of school science and environmental issues/problems. Moreover, detailed data concerning the children‘s views of NOS were not recorded—the researcher simply asked, *What is science?* Also, his data concerning the children‘s views of Nature was limited to eliciting students‘ definitions of what is the environment and identifying students‘ main environmental concerns (e.g., endangered species, pollution). Similarly, Kozoll and Osborne (2006) described the development of the relationship between a pre-service teacher‘s life-worlds of family, peers and school and his engagement with science, and how his worldview enabled him to integrate science and his everyday knowledge. The authors worldview focus was on the teacher‘s narratives of particular experiences with Nature, although these narratives included indications of his underlying beliefs about what the natural world is like and his relationship to it. The teacher‘s views of NOS were not examined. In addition to these studies, O. Lee‘s (1999) study involving Taiwanese students in Grades Four and Five, focussed on eliciting students‘ explanations about a hurricane, and comparing students‘ personal beliefs and scientists‘ (or a weatherperson‘s) explanation of the natural phenomenon. The researcher did not aim to elicit the students‘ views of the nature of science, or their views of the natural world other than hurricanes.

South African studies concerning worldviews and NOS views, as previously mentioned (page 21 and page 31), focus on indigenous knowledge systems in regard to worldviews (e.g., Dekkers & Mnisi, 2003; Linneman et al., 2003; Ogunniyi, 2004, 2005, 2007). There exists, therefore, a need to explore, in detail, the relationship between students' fundamental views of Nature and their views of NOS. Indeed, it has been reported that elementary school students' NOS views and worldviews are ―clearly under-researched" (Vhurumuku & Mokeleche, 2009). Moreover, this focus area has not yet been investigated in the South African context.

Chapter summary

The conceptual and theoretical framework employed in the present study began with a discussion of scientific literacy as a major goal of science education, and in particular, the need for students' to hold an informed understanding of the nature of science (NOS). Current research findings show that students' views of NOS are typically naïve. Worldview is one possible factor influencing students' NOS views, although the relationship between NOS and worldview (and in particular, students' views of the natural world) remains largely unexplored. Worldview and culture are closely related, and they influence the views of reality that students bring with them into the science classroom. Indeed, many students experience learning in science as a cross-cultural event, and in some cases, students experience worldview conflicts (e.g., between their religious beliefs and science). According to a coherence view of learning, students' existing conceptual frameworks control the process of learning by organising students' understanding of the world. Stated differently, meaningful learning in science depends on the new concepts being presented to students at school being related to students' existing knowledge and beliefs. Thus, in order to achieve the goal of scientific literacy and, in particular, in order to help students to develop an informed understanding of NOS, there needs to be meaningful integration of science knowledge into students' everyday thinking. Explanatory coherence theory presents a possible means of examining the coherence of the various concepts (such as, for example, views of NOS and views of Nature) within students' conceptual frameworks.

The contribution of the present study therefore lies in examining, in-depth, South African Grade Six students' views of the natural world (that is, their epistemological, ontological, emotional and status descriptions of Nature) and their views of NOS (i.e., their understandings about the tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative and creative aspects of NOS), and then exploring the coherence of these two domains. A greater understanding of the relationship between students' NOS views and their worldviews (and in particular, their views of the natural world), can help to inform teaching practices for improving students' scientific literacy, and in particular, increasing students' levels of understanding of the nature of science.

In Chapter Three, which follows next, details of the research design used and the data collection as well as analytic procedures employed, are described.

Chapter Three
METHODOLOGY

In this chapter, the research design of the current study is presented, and an overview is provided of the data collection and analysis procedures that were carried out. The design and administration of five data collection instruments is explained in detail, and includes a description and explanation of how the data collected by means of each instrument were analysed. Data for one case (Dyllan) are presented in the Appendices in order to clarify and illustrate how the various data collection and analysis procedures explained in this chapter were carried out.

In this first section, the research design of study is described, and an overview is provided of the particular data collection strategies that were employed.

Research design

The aim of the present study was to examine, in-depth, Grade Six students‘ views of NOS and of the natural world. In particular, the purpose of the study was to explore the little-known relationship between these two domains within the relatively unexplored context of South Africa.

Qualitative research design

A qualitative design has been advocated as the best strategy to use when conducting exploratory and descriptive research (Marshall & Rossmann, 2011; Miles & Hubermann, 1994) concerning little-known phenomena and novel populations (Marshall & Rossmann, 2011). Moreover, it is recommended that an exploratory strategy be used where the existing knowledge base is poor (Yin, 2009). In light of the paucity of knowledge concerning the relationship between students‘ views of NOS and their worldviews, particularly at elementary school level and in the South African context (Chapter 2, page 20), a qualitative design was employed in the present study.

A qualitative research design is also considered to be of value for research which aims to elicit and to understand the complexities and deep meanings of the views of individuals (Marshall & Rossman, 2011). Accordingly, qualitative data were collected in the present study, in order to elicit and analyse the students‘ understandings about NOS and their views of the natural world.

Multiple case study methodology

A case study methodology is suitable for addressing research questions that require an extensive and in-depth description of some issue (Cohen, Manion & Morrison, 2000; Yin, 2009). This is because a case study enables the researcher to focus on individual participants (Stake, 2000, 2005) and to develop rich and vivid descriptions of each individual (Cohen et al., 2000, 2007; Stake, 2000, 2005; Yin, 2009). Accordingly, the present study employed a case study methodology in order to understand the subtlety and complexity of the views of each Grade Six student. Moreover, as the evidence collected in a multiple case study is more compelling and robust than in a single-case design (Yin, 2009), the present study involved the in-depth study of fourteen cases. However, as cautioned by Cohen et al. (2000, 2007), the purpose of a case study is not to draw cause-effect conclusions, or to make generalisations from the results (Cohen et al., 2000, 2007).

The data collection strategies that were employed were written questionnaires and personal interviews, as described next.

Data collection strategies

Data collected from children can be meaningful and, when space is made for them, children's voices express themselves clearly (Mauthner, 1997). Written questionnaires and interviews are possible data collection strategies that can be used to elicit students' thoughts and views (Graue & Walsh, 1998). In the present study, written questionnaires were administered in order to collect background and personal data concerning the students, and as a means of eliciting the students' views of NOS. Interviews were employed as a means of eliciting detailed descriptions of the students' views of the natural world, and in collecting data concerning the schools' religious policies and the science teaching at each school.

Written questionnaires

The administration of questionnaires is a useful method that enables the researcher to collect data from a number of respondents simultaneously. Questionnaires can be completed rapidly, and when administered in the presence of the researcher, a good response rate is ensured. The researcher can also ensure that all questionnaire items are completed and filled in correctly, by checking participants' responses to all items when the questionnaires are returned (Cohen et. al., 2007). In the present study, the *Who am I?* questionnaire was the first questionnaire administered to students, the purpose of which was to collect personal and biographical details of all the Grade Sixes students at each school. The *Who am I?* questionnaire was carefully designed as a tool for locating particular individuals as cases for in-depth study (Chapter 2, page 38). To this end, and in line with accepted practice (Cohen et al., 2007), this introductory questionnaire comprised predominantly closed questions, which were quick to complete and straightforward to code. Cohen et al. (2007) caution that respondents may feel compelled to complete a questionnaire, especially when the instrument is administered in the presence of the researcher. All the Grade Six students at each school were asked to complete the *Who am I?* questionnaire during a prescribed lesson period. However, individuals could choose *not* to participate further in the study, by indicating as such in response to one of the items (this is described in more detail later [page 69]). Having identified a number of students for further participation in the study, a second written questionnaire was then administered, namely, the *VNOS-rs* questionnaire. The *VNOS-rs* questionnaire was carefully designed to capture rich and authentic responses from the students regarding their views of NOS. The *VNOS-rs* questionnaire therefore comprised open-ended questions, as advised by Cohen et al. (2007).

Both the *Who am I?* questionnaire and the *VNOS-rs* questionnaire were trialled and piloted in order to ensure the layout was attractive and uncomplicated, that the items were unambiguous and clear, and did not require too much time to complete, and to rehearse the coding system for the analysis of the data collected. Further details regarding the design and administration of these two questionnaires are provided later (page 67 and page 72).

Interviews

An in-depth interview strategy is suited to studies that aim to elicit individuals‘ knowledge and beliefs, and to capture the deep meaning of their views in their own words (Cohen et al., 2007; Kvale, 1996; Marshall & Rossman, 2011). Once students have reached elementary school, it is possible to use individual, semi-structured interviews with them (Christensen & James, 2001; Mauthner, 1997). Indeed, it is advised that ―[c]hildren know more than they know they know. They surely know more about what they know than the researcher does. The purpose of interviews is to get them to talk about what they know" (Graue & Walsh, 1998:112). However, Graue and Walsh (1998) note that students most likely have not had any experience with the typical sit-down research interview, and so this particular form of interaction is difficult to conduct with students—and the younger the students are, the more difficult it is. Students ―may not find sitting and answering an adult‘s questions an attractive activity" (Graue & Walsh, 1998:112). It is important, therefore, to negotiate the interviewing process with students (Graue & Walsh, 1998). Christensen and James (2001) concur that interviewing students poses particular practical and methodological problems (i.e., relating to language use, reliability and validity of accounts obtained from respondents, unequal power relations between adult interviewers and student respondents, as well as issues of confidentiality and ethics specifically concerning interviewing minors).

In order to overcome potential problems associated with interviewing young students, researchers are therefore advised to make the interview a non-threatening and enjoyable experience, and to establish trust and put the student at ease quickly (Cohen et al., 2007). Interviewers are further advised to use straightforward language, to allow the student time to think, and to combine various methods and activities during the interview (Cohen et al., 2007). A combination of activities, such as reading, sorting cards and talking, as well as the use of pictures, can be used to structure interviews with students and to gain their cooperation, sustain their attention more easily and to make the interview as stimulating as possible (Cohen et. al., 2007; Graue & Walsh, 1998; Mauthner, 1997). The use of pictures and other prompts also helps to equalise the power relations between the adult researcher and the student (Davis, 1998) as well as helping to overcome the problem of reticent or inarticulate students (Cohen et al., 2007).

Employing a standardised structured interview ensures uniformity and consistency in interview procedures across cases (Kvale, 1996), ensures that data are complete for each respondent in the topics that are addressed in the interview, and reduces interviewer bias effects (Cohen et al., 2007). A structured interview schedule also increases the comparability of responses, and facilitates the organisation and analysis of the data (Cohen et al., 2007). Reduced flexibility is a limitation of a standardised interview. However, this can be addressed, by, for example, inviting respondents to illustrate their responses by means of their own personal experiences (e.g., employing a think-aloud procedure [page 89]). In the present study, a standardised interview structure was employed in eliciting detailed descriptions from the students regarding their views of the natural world (i.e., worldview interviews).

In addition to conducting interviews in order to elicit respondents‘ beliefs and views (e.g., concerning the natural world), interviews can be used by the researcher to follow-up results and to probe deeper into the thinking underlying respondents‘ replies (Cohen et. al., 2007). In the present study, semi-structured interviews were employed in order to follow-up results—and to validate initial analyses—concerning the students‘ views of NOS and their views of the natural world (page 77 and page 95). Furthermore, semi-structured interviews were conducted with school principals and science teachers, in order to collect data concerning each school‘s religious policy and to determine the nature of the science teaching that was carried out at each school (page 63 and page 64). As recommended by Cohen et al. (2007), use of an interview guide enabled the various topics and issues to be covered to be specified in advance, thereby increasing the comprehensiveness of the data collected, and making the data more systematic for each respondent. Furthermore, in conducting the structured worldview interviews and semi-structured follow-up interviews with students, as well as the semi-structured interviews with school principals and science teachers, the interviews were conducted by a single researcher, in order to ensure consistency in the way that the interviews were carried out. Further details concerning the various interviews that were conducted, are provided later (pages 63, 64, 77 and 95).

Selection of participants

The aim of this exploratory study was to investigate the relationship between students‘ views of NOS and their views of the natural world (a component of worldview) (Chapter 2, page 31). It was therefore necessary to maximize the diversity of the views of Nature represented by the various cases, and yet to reduce the impact of factors, other than worldview, that might influence the students‘ views of NOS. To this end, a purposive selection strategy was employed, in line with recommendations made by Lincoln and Guba (1985). The need to control for other variables (as described below) was reinforced by the small size of the sample being studied. Moreover, Wengraf (2001) asserts that the logic and power of a purposive selection strategy lies in selecting information-rich cases for in-depth examination, and this is what the present study aimed to do.

According to Dreyer (2005), people‘s religious beliefs form part of their total outlook on life and the world, and their attitude towards and views about the natural environment. Furthermore, as explained previously, religion can be used as a marker of cultural diversity (Chapter 2, page 37). Consequently, in order to locate students who represented diverse views of the natural world, students belonging to the three major Abrahamic religions (i.e., Christianity, Judaism and Islam) were selected (Chapter 2, page 38). To this end, schools were identified that explicitly affiliated themselves with a particular religion, and then within each school, individuals were selected who demonstrated strong self-identified religiosity (i.e., Jewish, Christian, and Muslim students). Such individuals were located by means of the *Who am I?* questionnaire (page 67). Religion, however, is not the only factor shaping a person‘s worldview, and in particular, views of the natural world. Age, gender, nationality, language, and social class (Triandis, 1994) are factors that might also possibly also impact on students‘ views of Nature and their views of NOS (Figure 3.1). Accordingly, all these factors were taken into account in selecting the participants, as is explained next.

Age was not a variable amongst participants, as all the students were in Grade Six (Chapter 1, page 5), and therefore between the ages of eleven and twelve years old. In order to represent both gender groups, both boys and girls were selected. Language was controlled for by selecting students whose first language was English. The selection of English-speaking students

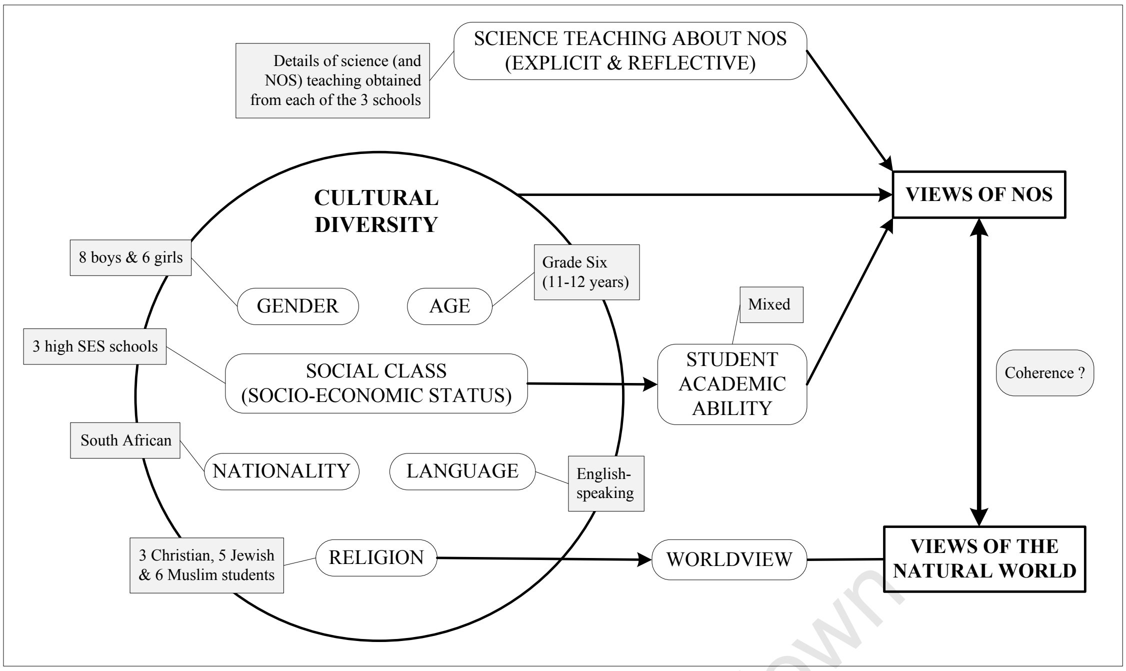


Figure 3.1: Diagrammatic overview of the various possible factors, relating to diversity and including worldview, that might impact on students' views of NOS

avoided the need for an interpreter and/or the translation of instruments, as advised by Triandis (1994). Furthermore, all the data could be collected by using exactly the same procedures, and the data collection could be carried out by a single researcher, which Triandis (1994) describes as the ideal. The variable of nationality was controlled for by selecting only South African students. Student ability is a further possible factor influencing a student's understanding of the nature of science, thus the relevant Grade Six teachers were asked to indicate the academic ability levels of each of the students in their classes.[3]

Regarding the factor of social class, annual school fees can be used as a marker of socio-economic status (SES) and therefore as an indication of social class (van der Berg, 2000). Furthermore, socio-economic status and the associated opportunity-to-learn is thought to be linked to school achievement (Anderson et al., 2001; Floden, 2002; Reeves, 2005)—including achievement in science. In order to identify possible schools for participation in the study, a box-and-whisker plot was compiled using data concerning the annual school fees payable at Western Cape schools in EMDC metropoles East, North, South, and Central (WCED, n.d.) for the academic year 2007. Distribution of the data showed that the lower quartile was R300 or less, and the upper quartile was from R2500 and above. Consequently, schools with annual fees for Grade Six of R0-R300, that is, with no or low annual school fees, were regarded as low SES

[3] Chapter 5 (page 211) includes a discussion of the limitations of the data concerning the students' academic ability levels.

schools. Schools with annual fees of R301 to R2499 formed the middle SES band, and schools with annual fees in excess of R2500 formed the high SES band.

Schools with specific religious affiliations were then identified within each SES band. There were found to be no Christian, Jewish or Muslim schools in the low SES band. All of the Jewish schools, and the majority of the Christian schools (albeit Catholic or Anglican), fell into the high SES band. The majority of the Muslim schools, with the exception of one school, fell within the middle SES band. Therefore, in order to locate three schools within the same SES band, a selection was made comprising one school from each religion in the high SES band, chosen randomly (where possible). However, before the final schools could be chosen, it was necessary to identify three different schools for the pilot study so as to avoid approaching the same schools again later. Consequently, the pilot study was conducted in a high SES Jewish school, a high SES Christian school, and a middle SES Muslim school. Evidence of the religious affiliation of each school was obtained by interviewing the various school principals in person, as described later (page 63).

To summarise, therefore, the students selected for participation in this study comprised South African students in Grade Six attending three high socio-economic status, English language schools in the Western Cape. Each school had a religious affiliation to one of the three Abrahamic faiths, that is, Judaism, Christianity, and Islam schools. Moreover, each of the selected students self-identified as belonging to one of these three Abrahamic faiths.

What follows next is an overview of the data collection and analysis procedures that were carried out. This is followed by a detailed description of the design and administration of the various data collection instruments, and the analyses of the various data that were collected.

Overview of data collection and analysis procedures

In order to optimise the time spent in meeting with individual students whilst also minimising the number of meeting times that needed to be set up with each individual, data for each case were analysed during the course of the data collection process. For example, students' responses to the *VNOS-rs* questionnaire were analysed before their individual worldview interviews were conducted, so that follow-up questions concerning the individual's NOS views and views of Nature could be asked during a single follow-up interview. In so doing, the need to schedule a separate NOS follow-up interview with each student was eliminated. Interweaving data analyses into the data collection procedure also reduced the delay of feedback for each student, thus making the process more meaningful to the individual students taking part in the study. A diagrammatic overview of the data collection—and data analysis—procedures is provided in Figure 3.2, and the various procedures are described thereafter.

In line with the advice of Cohen et al. (2007), research began only after the researcher was granted access to selected schools by the Western Cape Education Department (WCED) (Appendix 3.1, page 271). Contact was made with each of the school principals, first in writing (Appendix 3.2, page 272) and later in person, and each of the principals granted verbal permission for the research to be conducted at their school. Thereafter, arrangements were made for the researcher‗s first visit to the school, and the relevant teachers were informed hereof. During the first visit to the school, the researcher met with the principal and various teachers, and was introduced to the students in each of the Grade Six classes. As recommended by Cohen et al. (2007) and Mauthner (1997), during these introductory meetings, the purpose and nature of the study was briefly described to the students, but without so much detail that it might influence participants‗ responses later on during the data collection procedure. The researcher explained to the class what could be expected in terms of the various meetings that would follow during the course of the research process. As recommended by Cohen et al. (2007), a letter was handed to each student to take home, describing in broad terms the nature of the study, specifying the research procedure to be followed, and requesting written consent from each set of parents for their child to take part in the study (Appendix 3.3, page 274).

In order to select individuals for in-depth study, the Grade Six students at each school completed an introductory questionnaire, entitled *Who am I?*. The purpose of this written questionnaire was explained to the students and, when completing it, they indicated whether or not they were willing to participate further in the study, if selected. In so doing, as advised by Kvale (1996) and Cohen et al. (2007), written consent was obtained not only from the students‗ parents (by means of signed letters of consent) but also from the Grade Sixes themselves. Students‗ responses to the *Who am I?* questionnaire were then analysed, and a number of students were selected for participation in the in-depth study. Individuals who indicated they did not wish to participate further in the study were automatically excluded from the list of possible students. This was done in accordance with recommendations that participation be voluntary (Cohen et al., 2007; De Vaus, 2001; Kvale, 1996). A letter was also sent to the parents of each of the selected students, confirming their selection (Appendix 3.4, page 275). Meetings with the selected individuals typically commenced during the week following the selection procedure.

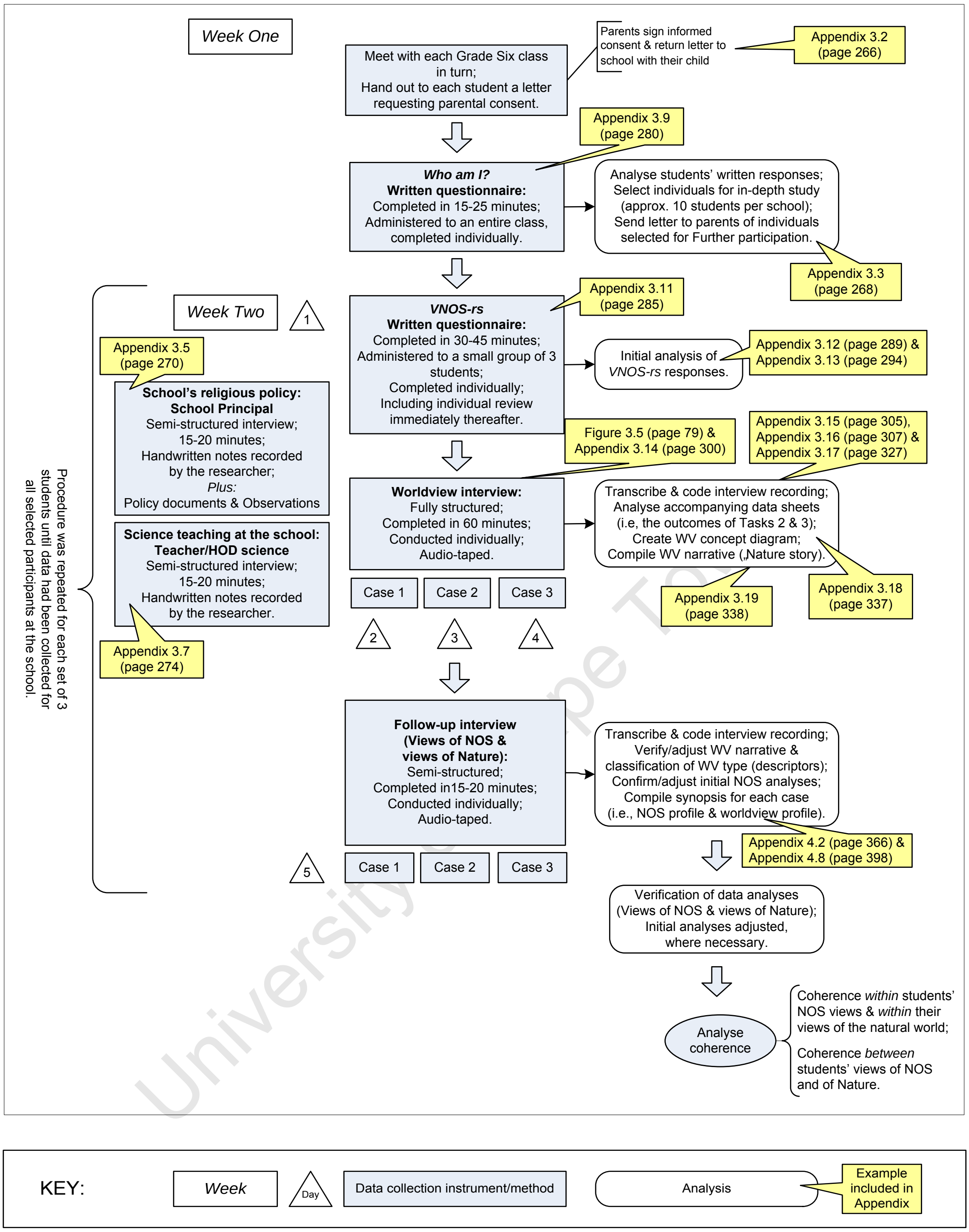


Figure 3.2: Diagrammatic overview of the data collection and analysis procedures that were carried out, after the participating schools were identified

It is advised (Christensen & James, 2001; Cohen et al., 2007; Mauthner, 1997) that the researcher creates an unthreatening environment for student participants by, for example, meeting with them in small groups. Therefore, at the beginning of the second week at the school, students were called in groups of three to meet with the researcher. They were asked to submit their signed parental consent forms, and then completed an individual, written questionnaire that had been designed to elicit their views about NOS (i.e., *VNOS-rs* questionnaire). After each student completed the questionnaire, the researcher sat with them to review their responses. The researcher also explained to each student what they would be doing in the meetings to follow. Permission was requested to record the upcoming interviews. The students' *VNOS-rs* responses were analysed that same day, and a schedule of questions was drawn up for each student as a guide for the follow-up interviews to be conducted later in the week.

The next step in the data collection procedure was to elicit respondents' views regarding the natural world (i.e., a component of their worldviews). This was done by conducting a structured interview with each student. One student was interviewed per day, so that on each day, the recorded interview could be transcribed verbatim within hours of the interview, in line with recommendations by Cohen et al. (2007). Analysis and coding of the interview transcript was therefore completed on the same day, and a concept map was then created, in order to compose a worldview narrative for each individual. Whilst analysing each student's views about Nature, questions needing further clarification were identified, in order to compile a semi-structured interview schedule that would guide the follow-up interview.

The final meeting with each student comprised an individual, follow-up interview. The purpose of these follow-up interviews was to seek clarification, where necessary, regarding students' views of NOS views and their views of Nature, and to verify the initial analyses of these data. Follow-up interviews were conducted with three students on a single day towards the end of the week. That same day, the recorded follow-up interviews were transcribed verbatim and coded, and the necessary adjustments were made to the initial data analyses.

After all the data had been collected and analysed, as described above, data analyses—concerning students' levels of NOS understanding and the categorisation of students' views of Nature in terms of a combination of bipolar worldview descriptors—were sent to independent researchers for the purposes of validation (this is explained in more detail later [page 79 and page 96]). Data for each case could then be analysed further in terms of coherence.

What now follows is a detailed description of the development and administration of each of the data collection instruments in turn, namely, interviews concerning each school's religious policy and approach to teaching science (and NOS), questionnaires concerning the students' personal and background information (*Who am I?*), questionnaires concerning the students' views of NOS (*VNOS-rs* questionnaire), interviews concerning the students' views of the natural world (worldview interview), and follow-up interviews conducted with each student. An explanation is also provided of the data analysis procedures that were carried out.

Moreover, data from one case (Dyllan) are provided as an illustration of the application of these various data collection—and analysis—procedures.

Data collection instruments and analyses of the data

Evidence of the religious policy of each school

The purposive case selection strategy employed in the present study, involved the identification of students with a strong religiosity and, in particular, students who self-identified as belonging to one of the three Abrahamic faiths (Chapter 2, page 59). It was considered that schools affiliated with a particular religion would most likely have students with a stronger religiosity. Thus, having selected three such schools, that is, a Christian school, a Jewish school, and a Muslim school (page 71), and obtained permission to conduct research with their Grade Six students, evidence was sought of each school‘s affiliation to their particular religion (in order to be able to then locate students with strong religiosity at each school [page 57]). To this end, a semi-structured interview was conducted with the principal of each school, using the interview schedule provided in Appendix 3.5 (page 276). These interviews took place in the principals‘ offices, and lasted approximately 15 minutes.

During the course of the each interview, the researcher recorded written notes. These notes were reviewed immediately after the interview in order to ensure that the data had been recorded accurately and in full. Additional evidence of the schools‘ various religious policies was obtained by means of policy documentation from the school (where available). Furthermore, field notes were recorded by the researcher, during her multiple visits to each school. These fieldnotes included descriptions of observations concerning dress code, conduct (e.g., greetings), religious artifacts and symbols, religious events, and so forth.

Design of the interview schedule for school principals

It was expected that schools without a meaningful religious policy would not be able to provide adequate evidence of their particular religious affiliation, nor would there be evidence of regular times at school being dedicated to religious activities. When interviewing each school principal, confirmation was first sought of the particular religion to which the school was affiliated (i.e., Question 1, Appendix 3.5, page 276). Specific details—and evidence—of the school‘s religious policy were then elicited (i.e., Question 2.a,b,c, Appendix 3.5, page 276). In particular, within the school‘s description of the basic principles underlying their approach to education and schooling, evidence was sought of references to, for example, a deity, holy scriptures, religious values, and so forth. In order to ascertain the extent to which the school‘s religious policy was carried out in practice, school principals were then asked to describe concrete examples of religious activities taking place at the school (e.g., prayer/devotional times and scripture readings, lessons dedicated to religious instruction, extra-mural activities such as Scripture Union Society, etc.), and to indicate the time allocated to such activities each week (i.e. Question 2.d,e, Appendix 3.5, page 276).

In light of the diversity of South Africa‘s general population (Alexander, 1996; Chidester, 1992; Prozesky, 1991; Triandis, 1994), it was expected that students from diverse backgrounds would be found in the school classrooms. However, there existed the possibility that schools with a strong religious affiliation might have a more homogenous population (e.g., at a Jewish school, the majority of students might be Jewish). To this end, principals were asked to indicate the composition of their student population (i.e., Question 3, Appendix 3.5, page 276). Before concluding the interview, principals were invited to make any additional comments.

Analysis of all the data obtained during the interview with the school principal—as well as observations recorded by the researcher by means of fieldnotes—were used to confirm the affiliation of each school to their particular religion. A summary of these data are presented in Appendix 3.6 (page 277).

Interviews regarding the science—and NOS—teaching at each school

The most significant factor at school influencing students‘ views of the nature of science is whether or not NOS is taught explicitly and reflectively (N.G. Lederman, 2007). One of the main aims of the present study was to explore the relationship between students‘ NOS views and their views of the natural world. It was therefore necessary to account for the science teaching (specifically, science teaching about NOS) at each school, as a possible alternative explanation in examining the students‘ NOS views in relation to their views of Nature.

Evidence of each school‘s approach to science teaching included data relating to the science curriculum being taught at the school and the school‘s general approach to teaching science, the amount of lesson time allocated for science teaching, the degree of teacher specialisation in teaching science, pressure to cover syllabus content as opposed to teaching additional understandings about science, as well as details concerning the teaching of particular ideas about NOS. In order to obtain these data regarding the science teaching at each school, individual, semi-structured interviews were conducted with the Grade Six science teachers, as well as with the Head of Science (HOD)[4] (if different to the science teacher/s) at each school.

[4] In some schools, where a particular learning area (e.g., Natural Science) is taught by multiple teachers, one of the teachers can be appointed as Head of Department (HOD). The role of the HOD includes managing the resources and the teaching programme of the department, by, for example, leading the

Each interview lasted approximately 15 minutes. Data from the interviews were recorded by the researcher in writing during the course of the interview, and these notes were then reviewed immediately afterwards, to ensure the data were complete and accurate.

In line with the recommendation of Cohen et al. (2007), the interview schedule was carefully designed so that details regarding the teaching of NOS would emerge from the teachers themselves, as opposed to teachers responding according to what they thought the researcher wanted to hear. To this end, the interview questions were initially very broad. However, should it have emerged that NOS was in fact being taught at the school, the interview schedule was designed to elicit details regarding *which* NOS concepts were included in the science teaching, and *how* such concepts were taught. An overview of the interview schedule (presented in Appendix 3.7, page 280) is provided next.

Design of the interview schedule for science teachers/HOD

In order to account for possible differences in science curricular content taught at the various schools, an introductory question (Question 1, Appendix 3.7, page 280) sought to confirm that the National Curriculum Statement (NCS) was being implemented at all three schools.[5, 6] The amount of time spent teaching science might also impact on students' understanding in science, and therefore teachers were asked how much time they spent teaching this subject each week (i.e., Question 2). Pressure to cover curriculum content is a factor influencing the teaching of NOS at schools (Abd-El-Khalick et al., 1998; N.G. Lederman, 1992). Moreover, the time spent teaching about NOS, as well as the approach to NOS teaching at a school, might be influenced by how much space there is for NOS in the science syllabus. In light of the absence of NOS-related concepts in the core content of the NCS for Natural Sciences[4] it was reasonable to expect that schools feeling under pressure to cover the required curriculum content would not include additional content in their teaching such as, for example, concepts relating to NOS. Question 3 (Appendix 3.7, page 280) was therefore designed to elicit teachers' responses about pressures relating to curriculum coverage.

Questions relating to each school's approach towards science teaching, focused on the degree

team of teachers in the delivery of the curriculum, and monitoring the quality of teaching and learning taking place within that particular learning area.

[5] The NCS is the current national curriculum that was designed (and subsequently revised) for South African schools. The implementation of the NCS was phased in over a period of four years, beginning in 2004. For Grade Sixes, the NCS was put into practice officially in 2005 (WCED, n.d.), but some schools were resistant to change. Independent and private schools (as opposed to public schools), in particular, did not immediately adopt the new curriculum in its entirety.

[6] The NCS for Natural Sciences (Grades R-9) does not include any explicit references to teaching particular concepts about the nature of science.

of expertise of the science teachers (i.e., whether science was taught by a specialist science teacher or by generalist class teachers) (i.e., Question 4, Appendix 3.7, page 280), and where (Question 6, Appendix 3.7, page 280) and how (Question 5, Appendix 3.7, page 280) the science teaching took place. Question 5 sought to elicit details regarding the school‘s overall approach towards the teaching of science. It was considered that some descriptions relating to teaching about NOS might have begun to emerge in response to Question 5 (e.g., teachers might mention, for example, that their policy was not only to teach the specified science syllabus but also to develop students‘ scientific literacy by teaching them about how scientists go about their work, how scientific knowledge is developed, etc.). Nonetheless, up to this point, the interview questions did not directly mention the nature of science. However, it was possible that NOS concepts might have been taught at the school despite not yet being articulated in a teacher‘s responses. Consequently, Question 7 tentatively asked teachers to name any ideas-about-science that were taught at the school (i.e., not referring to science content matter such as plants, phases of matter). If nothing regarding NOS was forthcoming at this point, teachers were then asked more directly, ―What is being taught regarding the nature of science?" (Question 7, Appendix 3.7, page 280).

In cases where teachers mentioned that ideas relating to NOS were being taught in science, the interview was designed to then elicit details concerning which broad ideas about NOS were being taught, and how these ideas were being taught (e.g., ideas relating to science as a way of knowing, the role of science in society, the nature of scientists‘ work, the values and beliefs inherent to scientific knowledge and its development) (i.e., Question 8, Appendix 3.7, page 281). If teachers described how some of these general NOS concepts were being taught at the school, an additional question would be posed to elicit further details regarding the teaching about particular aspects of NOS (such as, for example, the tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative/creative aspects of NOS) (i.e., Question 9, Appendix 3.7, page 282). In addition to the above nine questions, an optional final question was designed for teachers who continued to reply that they did not include any teaching about NOS. To this end, Question 10 (Appendix 3.7, page 282) sought to elicit the reasons as to why the nature of science was *not* being taught explicitly at the school.

In summary, the above interview schedule was designed to elicit from science teachers (and/or HODs), details regarding the explicit teaching of NOS-related concepts at the school. Data concerning the science—and NOS—teaching at each school are presented in Appendix 3.8 (page 284).

Students' personal and background details: *Who am I?* questionnaire

As indicated previously (page 60), the primary purpose of the *Who am I?* questionnaire was to gather personal background information regarding each student in all the Grade Six classes at the three schools (i.e., School C, School J, School M) in order to select suitable cases for in-depth study. The *Who am I?* questionnaire was designed to collect data regarding the religious and/or cultural background of each student, including their religion, nationality, and home language, as well as age, gender, parents' occupations, and socio-economic status. The next section describes the design and pilot-testing of the questionnaire. This is followed by a description of the administration of the questionnaire, and an explanation of how the data collected by means of this instrument were analysed.

Design of the Who am I? *instrument*

Using the criterion of face validity, clear and simple language was used in the construction of the *Who am I?* questionnaire items, and a complex structure of the questions was avoided, as recommended by Cohen et al. (2007). The layout was uncomplicated, the length short (i.e., administered in 15 to 25 minutes), and clear instructions were provided to guide students in completing the various items. Details of the development of the instrument are described here, including a description of the pilot test, and a number of comments regarding the administration of the final instrument. The final version of the *Who am I?* questionnaire is presented in Appendix 3.9 (page 286).

Part One of the *Who am I?* questionnaire (Appendix 3.9, page 286) was designed primarily as a tool to locate students who identified themselves strongly as belonging to a particular religion. To this end, a self-concept exercise, designed by Cumpsty (1991) to elicit information regarding respondents' identity or sense of self, was adapted. In response to the question, *Who am I?*, and as if giving the answers to oneself, the exercise consisted of numerous open-ended sentences beginning with the words, ‗I am…'. The sentences were designed to be completed fairly speedily, with the result that the foremost aspects comprising the individual's identity were most likely to be recorded first. In order to avoid this self-concept exercise (i.e., Part One) being too long and demanding for the Grade Sixes, only fifteen such open-ended sentences were included for the students to complete. Responses were sought to statements in which students self-identified as belonging to a particular religious or cultural group. Moreover, cases where this self-identification occurred within the first few (as opposed to the last few) statements—were regarded as having their religion/culture forming a more significant part of their sense of self and of their view of the world. Importantly, this self-identification was not prompted in any way by the researcher. In order to achieve this, the ‗I am…' task was located on the front page of the folded questionnaire booklet, so that students completed this task before reading the questions for Part Two that were located *inside* the fold (Part Two remained unread until Part One had been completed). For cases where students did not include their religious affiliation in their initial description of who they are (i.e., in Part One), this information was requested explicitly later (i.e., in Part 2, Question 8, Appendix 3.9, page 288). Moreover, De Wet (J. de Wet, personal communication, February 22, 2007) suggested that a way to ascertain a measure of the strength of a person‗s religious affiliation or ‗religiosity‗ is to ask how they would feel if their religion was criticised. To this end, Question 8.c was included to elicit students‗ reactions to personal religious criticism (Appendix 3.9, page 288). However, when analyzing students‗ religiosity, more weight was given to individuals‗ spontaneous descriptions (i.e., the responses recorded in Part One).

However, religion is not the only component of culture (Chapter 2, page 36). Additional cultural markers were therefore included in the *Who am I?* questionnaire in order to locate students with strong religious/cultural identities. These additional markers included the first and additional languages spoken at home (Part Two, Question 5, Appendix 3.9, page 287), and parents‗ occupations (Part Two, Question 6, Appendix 3.9, page 287). These data were elicited in the event that some students learnt languages at home other than those taught at school (e.g., Hebrew). Regarding parents‗ occupations, some occupations were regarded as being culture-specific (e.g., at the Christian school, one boy‗s father was a priest, and at the Muslim school, one girl‗s mother taught Arabic language classes at home).

Age, gender, nationality are further factors considered to shape an individual‗s worldview—of which views of the natural world form a part (Chapter 2, page 30). The first three questions of Part Two were designed to elicit these details from the Grade Sixes (i.e., Questions 1-3, Appendix 3.9, page 287). Socio-economic status is another possible cultural variable (Chapter 2, page 36). In addition to using annual school fees as a proxy for socio-economic status (Reeves, 2005) (page 58), De Wet (J. de Wet, personal correspondence, February 22, 2007) suggested it might be helpful to ask students for their own impressions of their family‗s socio-economic status. He said that students can be asked to indicate if they feel their family is ‗struggling‗, ‗doing fine‗, or if they feel their family is ‗well-off‗. Question 7 (Appendix 3.9, page 288) was included in the *Who am I?* questionnaire for this reason—although it is recognized that Question 7 is an inherently subjective and relative item. Area of residence might be another possible marker of socio-economic status, and therefore Question 4 (Appendix 3.9, page 287) was included to elicit from the students details of where they were currently living. Again, the limitation of this item is recognized, in that within the South African context, area of residence might be a marker of cultural/historical background rather than a definite indication of SES. Consequently, where necessary, responses to various items (i.e., Questions 4,6,7, Appendix 3.9, pages 287-8) in the *Who am I?* questionnaire were analysed in conjunction with one another.

In line with accepted practice (Kvale, 1996), in addition to obtaining written permission from parents for their children to participate in the study, consent was also obtained from the students themselves. Furthermore, it is recommended that students be given a real and legitimate opportunity to say that they do not wish to participate in a research study (Cohen et al., 2007). To this end, Question 9 (Appendix 3.9, page 288) was included at the end of the *Who am I?* questionnaire.

Pilot-testing of the *Who am I?* questionnaire

After designing the *Who am I?* questionnaire, the instrument was piloted with Grade Six students at a local elementary school. As recommended by Cohen et al. (2007), the pilot study was conducted in order to check the time needed to complete the questionnaire; the clarity of the questionnaire items, instructions and layout; to gain feedback on the response categories for certain items; and to try out the coding system for data analysis (Figure 3.3).

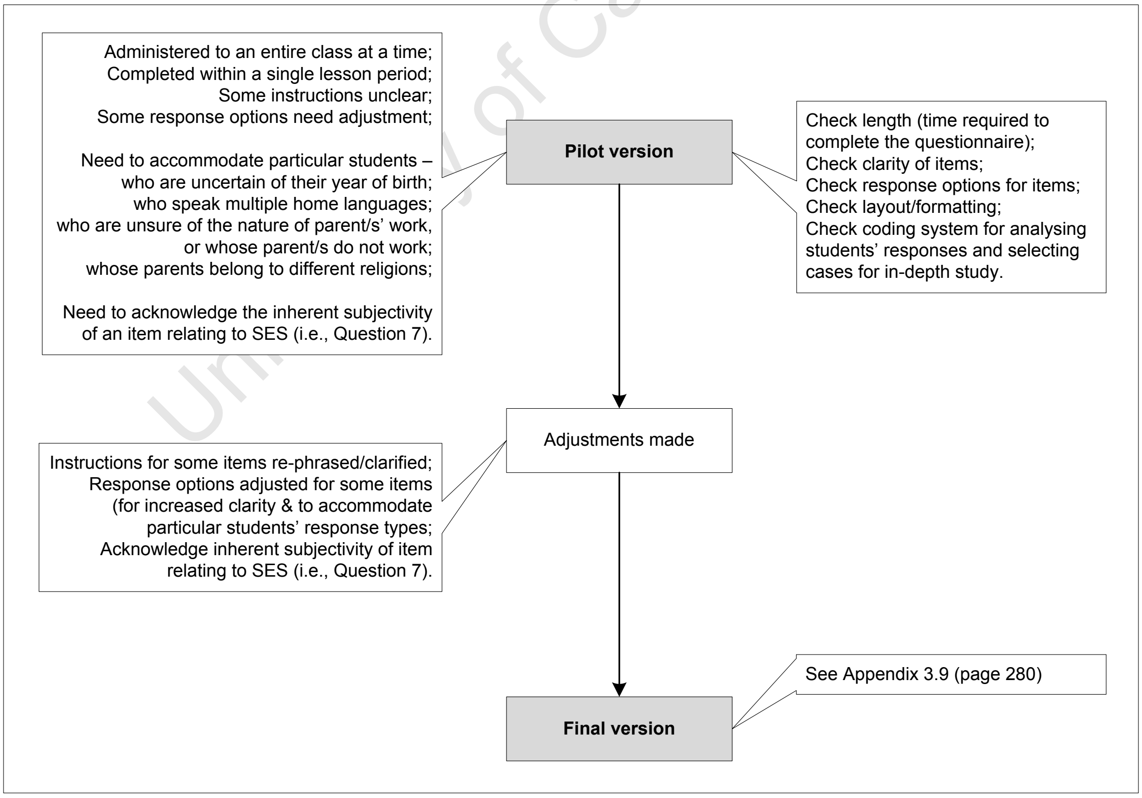


Figure 3.3: Diagrammatic overview of the development of the *Who am I?* questionnaire

During the pilot test, students completed their written responses to the *Who am I?* questionnaire in less than 30 minutes (i.e., in a single lesson period), which was considered to be an acceptable length of time. However, students‘ verbal feedback and written responses to the instrument revealed a need to adjust the phrasing of some of the questionnaire items. Question 1 (Appendix 3.9, page 287) (concerning student age) was amended in order to accommodate students who were unsure of the year in which they were born. Examples were added to the instructions for Question 3 (Appendix 3.9, page 287) (concerning students‘ place of birth) in order to help students in answering this item. Question 5.b (Appendix 3.9, page 287) (i.e., regarding language) was adjusted in order to accommodate students who spoke more than one language at home, and the instructions for Question 6 (Appendix 3.9, page 288) (concerning parents‘ occupations) were revised in order to accommodate students who were unsure of the kind of work their parent/s did, or whose parent/s did not work. The phrasing of Question 7 (Appendix 3.9, page 288) (regarding socio-economic status) was adjusted in acknowledgment of the inherent subjectivity of this item. Question 8 (Appendix 3.9, page 288) (regarding parents‘ religion/s) was adjusted in order to accommodate students whose mother and father held different religious beliefs from one another. Lastly, the response options for Question 9 (Appendix 3.9, page 288) (concerning students‘ willingness to participate in the study) were modified in response to one student‘s request for clearer differentiation between the meaning of a _Yes‘ and a _No‘ response.

Administration of the Who am I? *questionnaire*

The *Who am I?* questionnaire was administered to a whole class at a time, but completed individually. After preliminary introductions, and explanations regarding the researcher‘s purpose in visiting the school (page 60), the Grade Six students were then each provided with a copy of the *Who am I?* questionnaire. In order to elicit reliable responses from individuals, the students were requested neither to chat amongst themselves nor to look at others‘ response sheets whilst completing their own copy of the questionnaire. This was particularly important for the first section of the questionnaire, which required the students to identify the main characteristics/descriptors that differentiated them from anyone else, and where individuals‘ unprompted personal responses were of particular interest—in particular, individuals who self-identified as belonging to a particular religion and/or cultural (e.g., racial) group (page 57). If the students were to have started sharing their responses with one another, then it could have negatively impacted the validity and reliability of their responses. This potential threat to validity was addressed by locating the afore-mentioned open-ended portion of the questionnaire on page one (Part One), so that it was completed first—and while the students were more focused and with fresh attention. The remainder of the questionnaire (Part Two) comprised questions relating largely to respondents‘ personal and biographical details, and this information could not be copied from their peers. As such, possible peer contamination of results (Cohen et al., 2007) was addressed by means of the Part One-Part Two design and layout of the questionnaire.

Analysis of students' responses to the Who am I? *questionnaire*

As previously explained, a number of religious/cultural markers were embedded in the *Who am I?* questionnaire. In order to locate students who self-identified as belonging to a particular religion, their responses to Part One on the first page were analysed, that is, completing 15 sentences to describe who ‗I am…‘ (page 67). Additional markers included the language/s possibly spoken at home (i.e., Question 5, Appendix 3.9, page 287), the religion of the student‘s father and mother (i.e., Question 6, Appendix 3.9, page 288), how upset the student would feel if someone criticized her/his religion (i.e., Question 8, Appendix 3.9, page 288), and any further markers such as parents‘ occupations and items of religious dress worn by the student at school.

The following are examples of religious/cultural markers that were identified in students‘ responses to the *Who am I?* questionnaire: At the Muslim school, one boy self-identified as ―*I am…* Not even a little bit racist" (line 9); ―A muslim" (line 11); and, ―A person that is very religious" (line 12). Islam was the religion of both himself and his parents, and he responded that he would feel ―very upset" if someone criticized his religion. What is more, his father was a teacher at a local muslim secondary school, which had a strong religious policy. This boy was identified as a strong candidate for participation in the study. In contrast, another boy at the same school wrote that his family‘s religion was Islam, but that he would feel ―not at all upset" if someone criticized his religion. He did not include any cultural or religious descriptions in response to the ―*I am…*" section of the questionnaire. As this second boy did not identify himself strongly as belonging to a religion (i.e., in this case, the Muslim faith), he was therefore not considered a strong candidate for further in-depth study.

Of the total number of 105 Grade Sixes to whom the *Who am I?* questionnaire was administered at the three schools, 36 students were invited to participate in the study. The remaining students were not selected on basis of issues relating to permission, citizenship and religious affiliation (Table 3.1). However, for reasons relating to personal attitudes and response quality (Table 3.1), of these 36 individuals, data for fourteen students were finally studied in-depth.

To summarise, the *Who am I?* questionnaire was a tool that was employed as part of a purposive strategy in selecting students with diverse worldviews, whilst also taking into account other possible factors that might impact on students‘ views of NOS. The final selection of cases comprised 14 Grade Six students (8 boys and 6 girls) from diverse religious backgrounds (i.e., 3 Christian students, 5 Jewish students, and 6 Muslim students.

Table 3.1: Summary of reasons for not selecting students for in-depth study

General grounds for non-selection	Details regarding non-selection	Justification
Permission	Parents who did not wish their child to participate in the study. Students who did not wish to participate in the study.	Permission to participate needed to be granted by both the students themselves and their parents.
Citizenship	Non-South African citizens (e.g., students from Egypt, Israel, United Kingdom, United States, Zimbabwe)	The study was designed to explore the views of South African Grade Sixes.
Religion	Members of non-Abrahamic faiths (e.g., Hinduism, Atheism)	Religion was used as a marker of cultural diversity (in this exploratory study, the views of students belonging to the three Abrahamic faiths [i.e., Christianity, Islam, Judaism] were studied).
Personal attitude	Individuals who were unfocussed and restless during their meetings with the researcher; Also, students who were disruptive and who did not take their participation in the study seriously.	Meetings with such individuals were counter-productive.
Response quality	Students who were uncertain of their views, or who could not provide adequate explanations/illustrations to support their views; Students whose explanations were unclear or lacked sufficient detail; Students who relied too heavily on supplementary prompting by the researcher to articulate their views.	‗Think aloud' insights were important in understanding students' thinking and for making connections between an individual's various ideas/views. Reliability of the data might have been compromised if the researcher had to rely too heavily on the use of leading questions to elicit adequate responses from students (Cohen et al., 2007; Kvale, 1996).

Appendix 3.10 (page 289) presents a summary of the students finally selected for participation in the study.

Views of the nature of science: *VNOS-rs* questionnaire

In order to elicit the Grade Six students' views of NOS (in particular, their views regarding the tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative/creative aspects of NOS, as well as the role of science and the nature of scientists' work), an elementary school version of the widely-used *Views of Nature of Science (VNOS)* instrument *(i.e., VNOS-E)* was adapted and re-named *VNOS-rs* (Chapter 2, page 24). An early version of the *VNOS-rs* instrument was trialled and adjusted. The revised *VNOS-rs* questionnaire was then piloted, and a few minor adjustments were made, before the final version of the instrument could be administered (page 74). Figure 3.4 presents a diagrammatic overview of the procedure for developing the *VNOS-rs* questionnaire, and this is followed by a description of each stage of the process of trialling, piloting, adjusting and finalising the *VNOS-rs* questionnaire. The final instrument is presented in Appendix 3.11 (page 291).

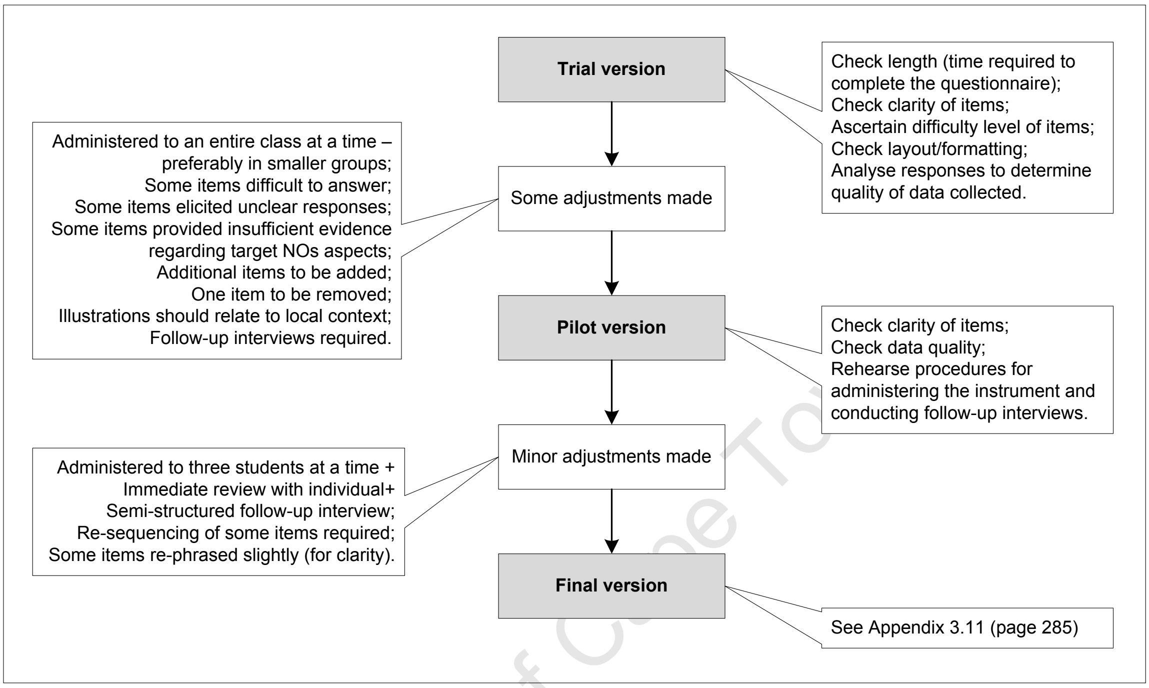


Figure 3.4: Diagrammatic overview of the procedure for developing the VNOS-rs questionnaire

Trial version of the VNOS-rs *questionnaire*

An early version of the *VNOS-rs* questionnaire was trialled with three Grade Six classes at a local elementary school. The purpose of this trial was to check the amount of time needed to complete the questionnaire, to check the clarity of the questions and the level of difficulty it posed for students, as well as to determine the quality of the data obtained when analysing the data collected by means of the instrument.

Most of the students in the trial completed the written questionnaire within 30 minutes and the overall feeling expressed by them was that the instrument was easily understandable and could be completed without too much difficulty. When students were asked why some questions had been left unanswered, they replied that they did not know the answers to those questions. In response to the trial, some adjustments were required concerning the contents of the questionnaire items (i.e., re-phrasing or adding emphasis to existing questions, adding additional questions, and removing a question) and concerning one of the illustrations. The procedure for administering the *VNOS-rs* also required some improvements, as described later (page 75).

Introductory questions (i.e., Questions 1.a, 1.b, 1.c, 2.a, 2.b, Appendix 3.11, page 292) were revised in order to elicit clearer responses concerning students‘ views of the role/purpose of science and the ways in which scientists work, as it was considered that such views might be linked to students‘ views of the natural world (Chapter 4, page 106). Emphasis was added to a question concerning the tentative nature of science (i.e., Question 4.a, Appendix 3.11, page 292) in order to elicit students‘ views on whether *existing* scientific knowledge is subject to change, as opposed to eliciting responses concerning the addition of new knowledge (for example, due to advancements in technology). In order to elicit students‘ views regarding the empirically-based and theory-laden aspects of science, questions were added in the revised version of *VNOS-rs*, concerning whether or not science is only based on facts (i.e., Questions 4.c, 4.d, Appendix 3.11, page 293), and regarding scientists‘ knowledge about dinosaurs (i.e., Questions 5.a, 5.b, Appendix 3.11, page 293). In order to elicit students‘ views regarding the reliability of scientific knowledge, questions were added concerning the extent to which scientists can be trusted (i.e., Question 3.a, 3.b, Appendix 3.11, page 292). Emphasis was added to the question concerning the reasons for disagreements amongst scientists (i.e., Question 5.c, Appendix 3.11, page 293), in order to elicit students‘ views relating to the socially- and culturally-embedded aspect of science and regarding views of science as a human endeavour (rather than eliciting students‘ knowledge of various theories explaining the extinction of dinosaurs). The item relating to weather forecasts (i.e., Question 6.a, Appendix 3.11, page 293) was re-phrased slightly in order to elicit students‘ views of the empirically-based aspect of NOS. The visual appeal and relevance of the *VNOS-rs* questionnaire was improved by replacing one of the illustrations with a South African alternative (i.e., the map alongside Question 6.a, Appendix 3.11, page 293).

The first version of the *VNOS-rs* questionnaire included a question relating to the distinction between scientific laws and theories. However, when trialling the instrument, it was found that students‘ responses to this item were typically incomplete, or their responses lacked sufficient clarity and detail for the purposes of analysis. A discussion with a researcher, who has extensive experience in studying the NOS views of elementary students, revealed that their own studies have found students of this young age are usually unable to distinguish between scientific theories and laws. As this questionnaire item does not yield any meaningful results, it is no longer included when assessing the NOS views of elementary school students (J.S. Lederman, personal communication, January 5, 2007). In line with this advice, the item concerning the distinction between scientific theories laws and theories was removed from the *VNOS-rs* questionnaire.

Pilot-testing of the revised VNOS-rs *questionnaire*

Having trialled the early version of the *VNOS-rs* questionnaire and made the adjustments as described above, a revised version of the instrument was piloted at a further three elementary schools. As recommended by Cohen et al. (2007), the pilot tests were conducted in order to eliminate any unclear or problematic items, and to check if the revised version of the instrument would now more effectively elicit sufficient data regarding the students‘ NOS views. The pilot test also served as a means of checking the procedure for administering the questionnaire and conducting semi-structured follow-up interviews (page 77). A number of adjustments were made as a result of the pilot test. These involved the re-sequencing of questions relating to the first item (i.e., Questions 1.b, 1.c, Appendix 3.11, page 292) and a slight re-phrasing of two further items (i.e., Question 4.d, and Question 7.b, Appendix 3.11, page 293-4) in order to simplify and clarify instructions for students. Details of the contents of the final *VNOS-rs* questionnaire are provided next, followed by a description of the administration of the instrument.

Final version of the VNOS-rs *questionnaire*

The final version of the *VNOS-rs* questionnaire is presented in Appendix 3.11 (page 291). An overview of the various items—and the NOS aspects related to each—is provided in Table 3.2.

Administration of the VNOS-rs *questionnaire*

As already mentioned (page 73), analysis of the students‘ written answers to the trial version of the *VNOS-rs* questionnaire revealed that their responses were sometimes incomplete. Also, some students‘ responses lacked the detail needed in order to determine whether their understandings of each of the various NOS aspects were naïve, developing or informed. Follow-up interviews with individual students were therefore required. Furthermore, it was considered that administering the questionnaire to smaller groups of students at a time, would allow for individualised checking of students‘ completed questionnaires, thereby improving the response rate.

Accordingly, during the pilot study, the *VNOS-rs* questionnaire was administered to three students at a time (and completed individually). As each student finished completing their questionnaire, the researcher read through the questions with them, and where necessary, asked for answers to be explained in more detail. In some cases, students wrote additional answers on their questionnaire pages, and in other cases the researcher noted the student‘s additional comments verbatim on the questionnaire response sheet. Using this opportunity to probe students for immediate clarification on their NOS ideas served a dual purpose: On a practical

Table 3.2: Overview of items included in the *VNOS-rs* questionnaire, and views of various aspects of NOS possibly elicited by each questionnaire item

Item no.	Question	Related NOS aspects
1.a	What kind of work do scientists do?	Nature of scientists' work Empirical evidence
1.b	*Where* do scientists do their work?	Nature of scientists' work Role/purpose of science Empirical evidence
1.c	*Why* do scientists do the work they do?	Role/purpose of science
2.a	Do all scientists work in the *same way*? Yes/No	Nature of scientists' work
2.b	Briefly describe how scientific *experiments and investigations* are done.	Nature of scientists' work Empirical evidence
3.a 3.b	Do you think we can trust what scientists tell us? Yes/No Please explain your answer for (3.a).	Tentative Socially- and culturally-embedded
4. a 4.b	Do you think scientists will *change their minds* about *existing* science facts in the future? Yes/No Please describe an example to explain your answer for (4.a).	Tentative Theory-laden
4.c 4.d	Is science only based on *facts*? Yes/No Please give an example or explain your answer for (4.c).	Empirical evidence Theory-laden Imagination and Creativity
5.a 5.b	*How do scientists know* what dinosaurs looked like and what they ate? How *certain* are scientists about their knowledge of dinosaurs? Very unsure / Little bit unsure / Certain / Very certain	Empirical evidence Theory-laden Imagination and Creativity
5.c	*Why* do scientists sometimes *disagree* about the answers to questions?	Socially- and culturally-embedded Imagination and Creativity
6.a	*How* do scientists predict what the weather will be like for the next few days?	Empirical evidence Theory-laden Imagination and Creativity
7.a 7.b.i 7.b.ii	Do you think scientists use their *imaginations and creativity* when they do their work? Yes/No If you answered NO to (7.a), please explain *why*. If you answered YES to (7.a), describe *when* you think scientists use their imaginations and creativity.	Imagination and Creativity

level, this interaction with each student addressed the need to engage students who had completed their questionnaire before the others in the group, thereby minimising possible disruptions to those students who had not yet finished. More importantly, this time spent engaging immediately with each student maximised the opportunity for follow-up questions to be addressed to individuals as soon as they had completed their *VNOS-rs* questionnaire. As such, the students' initial ideas (i.e., those ideas they had recorded in writing on their *VNOS-rs* questionnaires) were still fresh in their minds, and therefore it was easier for them to explain their thinking further, where necessary. Individual, semi-structured, follow-up interviews with the students followed two to three days later, after the researcher had completed an initial analysis of the students' responses, and identified particular responses to be probed further.

In light of the above-mentioned improvements in administering the *VNOS-rs* questionnaire, the final *VNOS-rs* instrument was administered to three students at a time, but completed individually. Immediately as each student completed their written answers, the researcher sat with them to review their responses. This procedure required approximately 30-45 minutes in total. Three days later, a semi-structured interview (lasting approximately 15-20 minutes) was conducted with each student in order to clarify any remaining queries regarding their views of NOS.

Venues for the administration of the final *VNOS-rs* questionnaire

In all three schools, the venue used when administering the *VNOS-rs* questionnaire was the same venue that was used when conducting the individual worldview interviews and the follow-up interviews. As recommended by Wengraf (2001), a neutral venue was sought in which the researcher could meet with the students, undisturbed. The room used for remedial lessons served as a quiet, comfortable and practical space at School M, a remedial room and a private section of a vacant seminar room were used at School C, and a small unused computer room was used at School J. Desks and chairs were available in each of these venues, and meetings between the researcher and the students were generally uninterrupted. On the odd occasion when an apologetic staff member knocked on the door because they had wanted to sit and work there quietly, the students were typically engaged in meaningfully conversation with the researcher and therefore were not disturbed by the minor interruption.

No significant peer contamination of responses

Whilst students completed the *VNOS-rs* questionnaire, there was a need to minimize opportunities for interaction between them, such as, for example, looking at one another's answers and/or discussing their ideas. To this end, the three students were each allocated their own desk on which to work, and the desks were positioned apart from one another in the room. From the outset, and as advised by Cohen et al. (2007), students were reassured that there were no correct or incorrect answers, that it was their own views and thoughts that were sought, and they were encouraged not to be concerned with comparing their own answers to that of their peers. Students were also explicitly asked not to discuss their ideas amongst themselves whilst completing the questionnaire. Although it was not possible to prevent individuals from chatting together afterwards, there seemed to have been no significant peer contamination of the students' responses in the time lapse between the initial completion of their written *VNOS-rs* questionnaires and their follow-up interviews. This claim is supported by evidence collected during the individual follow-up conversation that was held with each participant immediately after completing the *VNOS-rs* questionnaire, as well the follow-up interview that was conducted a few days later, in which students' expanded descriptions and supplementary illustrative examples supported their initial written responses.

Analysis of the students' NOS views

As explained above, the NOS views of each student were elicited by means of a written *VNOS-rs* questionnaire with immediate review, and a semi-structured follow-up interview. The students' NOS responses were analysed according to an analytic framework that was developed for the present study, as described next.

Development of the analytic framework for NOS

The analytic framework for NOS that was employed in this study, was developed from various international curriculum and reform documents (i.e., AAAS, 1989, 1993; NRC, 1996; NSTA, n.d.) that describe the kinds of understanding that constitute an informed view—as opposed to a naïve view—of NOS. Extracts from these documents were used to draw up an analytic framework in the form of a series of tables (Appendix 3.12, page 295, Tables 3.12-1 to 3.12-5). A separate table was drawn up for each of the five NOS aspects being studied (i.e., tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative/creative aspects). Each table provided details of the contents of sample NOS views that might be articulated for three levels of understanding about NOS (i.e., informed, developing, and naïve). Two independent NOS researchers confirmed that the NOS analytic framework was a comprehensive and most helpful analytic tool (F. Lubben, personal communication, March 25, 2010; K. White, personal communication, August 6, 2009).

Description of procedure for the analysis of the students' NOS views

In order to determine the students' levels of understanding about the five NOS aspects being investigated (i.e., tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative/creative), all the NOS data for each case were analysed, namely, students' written responses to the *VNOS-rs* questionnaire and the supplementary notes added during the immediate review process, as well as the verbatim transcriptions of the semi-structured follow-up interviews. Each NOS statement was first coded with regard to the NOS aspect/s to which it related (e.g., tentative), before being compared with the analytic framework to determine the level of understanding the statement represented (e.g., an informed view). Some NOS statements related to more than one aspect (e.g., tentative, and theory-laden aspects), and some students described views relating to more than one level of understanding (e.g., statements indicating both informed and developing levels of understanding) (Chapter 4, page 122). Importantly, where multiple responses from a student were related to a single issue (such as, for example, disagreements amongst scientists), these related statements were considered together in analysing the student‘s overall view concerning this particular issue scientists (i.e., a student‘s written answer on the *VNOS-rs* questionnaire, a statement recorded during the immediate review process, and a further explanation provided during the follow-up interview). Furthermore, in using the analytic framework to determine the level of understanding of a student‘s NOS views (e.g., regarding the tentative aspect of NOS), it was not required that the student necessarily refer to all the possible points included in the analytic framework for that particular level of understanding. Rather, in each NOS statement of the student, evidence was sought of any components of, for example, an informed understanding of the specific NOS aspect in question. This particular analytic approach was validated by two independent researchers of NOS.

Having coded every NOS statement according to the relevant NOS aspect/s and level/s of understanding, all of the statements relating to a particular NOS aspect were then considered together, in order to determine the overall level of understanding of the student about a particular NOS aspect (e.g., statements relating to the empirically-based aspect of NOS). This analytic procedure was completed for each of the five NOS aspects in turn. Appendix 3.13 (page 300) illustrates the outcome of this analytic procedure for Dyllan.

For each case, having determined the student‘s overall level of understanding about each of the five NOS aspects, an individual NOS profile was then created (Chapter 4, page 126). The NOS profiles of the fourteen cases could then be compared with one another. Furthermore, in order to explore the extent of the coherence between the students‘ views of NOS and their views of the natural world, the NOS profile of each student could be compared to their worldview profile.

Verification of data analyses

Analyses of the NOS data were verified by two independent researchers of NOS. The two researchers were provided with a full set of NOS data for three cases, along with details of the corresponding questions from the *VNOS-rs* questionnaire and the follow-up interview, and the series of five tables constituting the analytic framework for NOS. For each of the three cases, the researchers were asked to read through the NOS responses of the student, determine which *NOS aspect/s* each statement related to, and then to determine the *level of understanding* indicated by each statement. They were also asked to classify the *overall* level of understanding for each NOS aspect. Overall, there was found to be an agreement of 73.5% in the outcomes of the researchers' analyses, and this served to validate the accuracy of the analyses of the NOS data that had been conducted thus far. Further analyses of the NOS data proceeded with the identification of common themes amongst the range of the students' views of NOS, as is described next.

Further analysis of the students' NOS views: Themes

Whilst analysing the NOS data for the fourteen cases, common response types began to emerge amongst the data, and these were therefore recognized as themes. Themes were identified by grouping together similar responses, and then assigning a theme label and a theme definition to each theme (Chapter 4, page 109).

Further to analysing individuals' levels of understanding pertaining to each of the five NOS aspects, and creating a NOS profile for each case, as well as identifying common themes amongst the range of students' views of NOS, the students' NOS views were examined in regard to internal coherence, as well as coherence between their NOS views and their views of the natural world. Details of these coherence analyses are provided in a later section (page 102).

Views of the natural world: Worldview interview

The students' views of the natural world were elicited by conducting individual, structured worldview interviews, which employed a modified version of the interview schedule used by Cobern (2000b) in his study of Grade Nine students' conceptualisations of Nature.

The activity-based interview consisted of three main tasks, which involved the use of various visual and text-based elicitation devices. Task One was designed to introduce students to the topic of Nature (by means of a visualisation activity) and to elicit their definitions of the natural world (with the use of a collage of images of Nature). During Task Two, students were asked to sort and group various words in relation to Nature, and in Task Three students sorted and ranked a variety of Nature-related statements. The role of the interviewer, as described by Cohen et al. (2007) and Kvale (1996), was to listen actively, to seek confirmation of interpretations of what the students said, to check the reliability and internal consistency of their responses, and to ask probing questions and to encourage the students to speak freely and at length.

Figure 3.5 provides a diagrammatic overview of the interview structure, which is described in more detail later (page 85). What follows next is a description of the procedure for developing the interview schedule, before presenting the details of the final version of the instrument. An explanation of the analysis of the data concerning the students' views of the natural world, is

TASK ONE:

Collage of images

(cf. page 86)

1. Clarify use of terminology: “nature”, “the natural world” and “the natural environment”.
2. Begin with the child’s own mental image of nature (i.e., Imagine you are in nature, where are you, describe what it is like, etc.)
3. Look at these pictures. (Which parts are nature? Not nature?)
4. What would you like to still find out about nature?

5.a. Do you think we can know things about nature?
5.b. What kinds of things can we know about nature?
5.c. Who finds out these things?
5.d. How do they find it out?
5.e. Why do we need to know these things? Why do they find out things about nature?

Understandable	Predictable	Orderly
Confusing	Mysterious	Complicated
It changes	Holy	Spiritual
Powerful	Frightening	A mixture of different things
Can see it and touch it	Beautiful	Fascinating
Just there	Ordinary	Can be used
We need it	Pure	Over-used
Ruined		

TASK TWO:

Word Sort & Sub-group

1. Group each word: “Nature is” or “Nature is not”.
2. Think-aloud (explain a reason, describe an example).
3. Form sub-groups of related words.
4. Talk about each sub-group of words:

4.a. Explain why they are grouped together.
4.b. Justify chosen sequence for talking about each sub-group.

	Without the things that we get from nature we could not enjoy the everyday life we have today.
Nature is something that should be studied so that we can learn more about it.	Nature is difficult to understand.
I enjoy nature.	Nature is dangerous
There is chaos in nature.	In nature I see the work of God.
Nature can be repaired.	I believe nature needs to be protected.
I am worried about the pollution and the damage it does to nature.	Nature is an everyday part of life that I normally do not think much about.
I view nature as something solid, large and reliable.	Things happen in nature for a purpose.
The natural world is all there is, all there ever was, and all there ever will be.	There is more to nature than what we can just see and touch.

TASK THREE:

Statement sort & Dyad comparison/rank

1. Group each statement: “Agree/Yes” or “Disagree/No”.
2. Think-aloud (explain a reason, describe an example).

3.a. Compare statements in pairs, and select the stronger view each time.
3.b. Each time, explain reason for each statement chosen to keep.

Figure 3.5: Overview of the structure of the worldview interview

provided thereafter.

Development of the worldview interview schedule

As recommended by Cohen et al. (2007), for the purposes of the present study involving Grade Sixes, Cobern‘s (2000b) interview schedule was trialled, piloted and adjusted. Adjustments were largely related to the contents of the various elicitation devices, and the recording of the interview, and the analysis of the data that were collected. Figure 3.6 presents a diagrammatic overview of the procedure for developing the worldview interview schedule, which is followed by a description of the trialling and pilot-testing of the interview schedule.

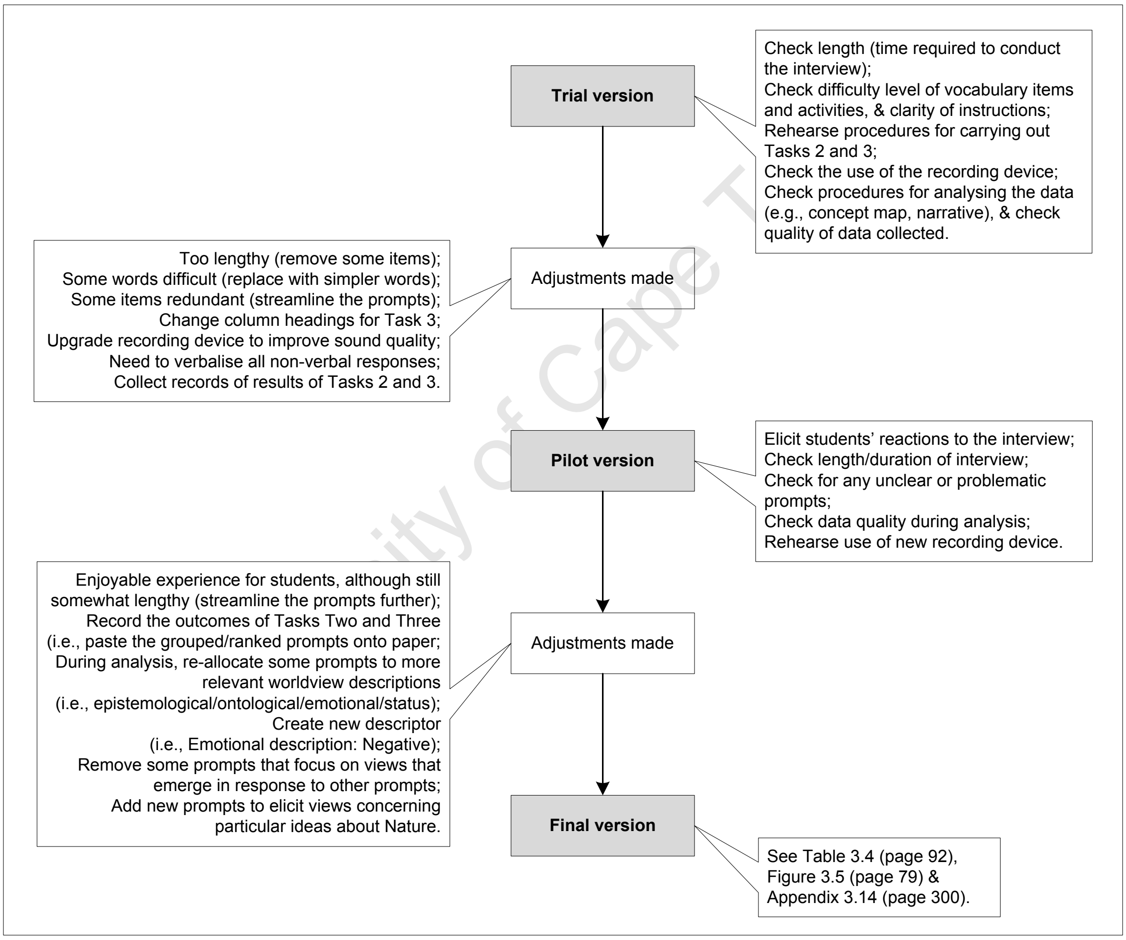


Figure 3.6: Diagrammatic overview of the procedure for developing the worldview interview schedule

Trial version of the worldview interview

The worldview interview schedule was initially trialled with Grade Six students at a local elementary school. Prior to the trial, an experienced teacher at the school was consulted in order to check the difficulty level of the proposed words to be used in the elicitation devices (i.e., in Tasks Two and Three). In addition to checking the difficulty level of the various probes, the purpose of trialling the interview schedule was to check the contents of the elicitation devices and the quality of data they yielded. There was a need to determine the length of time required to conduct each interview, and to determine students‘ personal reactions to participating therein. Trialling the worldview interview also provided opportunities to check the procedures for carrying out the various interview activities and recording the interviews, as well as rehearsing the coding and analysis of the data that were collected.

The worldview interview was trialled with the Grade Sixes after school-hours, and therefore there were no time restrictions imposed on the researcher. The students participated willingly throughout, yet the interview was considered to be a lengthy experience. It was also found that a number of the prompts were unnecessarily repetitive, and therefore students found themselves wanting to repeat their earlier explanations and illustrations. Consequently, there was a need to streamline Tasks Two and Three by removing some prompts (e.g., *Knowable*, *Unexplainable*, *Living*). Other prompts were converted, for example, from a word prompt (Task Two) to a statement prompt (Task Three) (e.g., *Dangerous* was converted to *Nature is dangerous*; *Chaotic* was converted to *There is chaos in Nature*). Terms which were unfamiliar to students and therefore typically required explication, were replaced with more understandable alternatives (e.g., *Doomed* was replaced by *Ruined*; *Physical* was changed to *Can see it and touch it*; *Can be restored* was re-phrased as *Can be repaired*). Furthermore, there were statements in Task Three that were re-phrased and made more concise (e.g., *Full of things we can use* was re-phrased as *Can be used*; *Nature is a result of purpose and things happen in Nature for a purpose* was re-phrased simply as *Things happen in Nature for a purpose*; *I like Nature and I enjoy it* was shortened to *I enjoy Nature*). The column headings provided for students to use when sorting the statements in Task Three, were also adjusted slightly for the sake of clarity. (i.e., *Agree* and *Disagree* headers were replaced with *Yes/Agree* and *No/Disagree*, respectively).

In addition to the above-mentioned adjustments that were made to the contents of the worldview interview, trialling the interview schedule highlighted a number of necessary improvements pertaining to the recording of the interview data. First, there was a need to upgrade the recording device used in the trial to a digital audio recorder, which could record an entire interview without any interruption in the recording. The new audio recorder also produced better sound quality for the purpose of transcribing the interviews later. Second, when trialling the worldview interview, it became apparent that there was a need to verbalise all non-verbal responses and actions for the sake of the audio recorder and the interview transcript. For example, when a student pointed to a particular word- or statement-prompt and said, ―this one”, there was a need for the researcher to repeat, verbally, the particular word/statement that was reflected on that prompt. For the purposes of transcription and analysis later, there was also a need to read aloud the results of the various sorting and ranking tasks (i.e., Tasks Two and Three) and to record the outcomes of these tasks on paper. Having made the necessary adjustments to the worldview interview schedule (as described above), the instrument was then piloted, as detailed next.

Piloting of the worldview interview

The worldview interview was piloted with Grade Six students at three elementary schools. The purpose of the pilot was to elicit students‗ general reactions to the interview, to check the time need to complete each interview, to identify any unclear or problematic items, to check the quality of the data obtained when analysing students‗ responses, and to rehearse the use of the new recording device.

Feedback from the students revealed that they enjoyed their worldview interview. However, in order to complete the interview within the teaching periods pre-determined by the school timetable, the researcher sometimes felt a need to ‗hurry along‗ the activities. It was therefore decided to reduce the length of the interview further, by streamlining the prompts further, where possible, but without compromising the quality of the data obtained. To this end, a number of prompts were removed, for example, where it was found that students had typically described views relating to a particular prompt in response to a previous prompt (e.g., In task Two, students referred to endangered species when explaining their views relating to two prompts, namely, *Endangered* and *Over-used*).

Analysis of the worldview data collected during the pilot test revealed a need to create an additional bipolar descriptor for categorising students‗ emotional descriptions of Nature. That is, emotional descriptors were expanded to include not only Positive and Neutral emotional responses, but also Negative emotional responses. Analysis of the pilot interview data further revealed a need to re-allocate some prompts to more relevant worldview descriptor categories (e.g., the Task Two word prompt *Frightening* was assigned to the Negative bipolar descriptor). There was also a need to include additional prompts, which were designed to elicit students‗ views concerning particular aspects of the natural world that were not yet adequately elicited by means of the existing prompts (e.g., *We need it* was added to Task Three in order to elicit views beyond merely whether Nature is useable, but also the extent to which we *need* to use it; *Ordinary* was added in order to elicit students‗ views of the natural world being ‗mundane and prosaic‗ or as ‗something beyond the ordinary‗).

Final version of the worldview interview

In the final version of the worldview interview, Task Two was reduced from 28 words (in the pilot version) to 22 words, and Task Three was reduced from 18 statements (in the pilot version) to 15 statements (Table 3.3). The worldview interviews could therefore be conducted within 45-60 minutes, fitting comfortably within the constraints of the school teaching timetable. The improvements made to the interview schedule helped to refine and streamline the instrument, whilst still enabling comprehensive data to be obtained concerning students‘ epistemological, ontological, emotional, and status descriptions of the natural world. A description of the administration of the finalised worldview interview schedule is provided next.

Worldview interview structure

An overview of the structure of the worldview interview has already been presented (page 80). Further details concerning each of the interview tasks are provided here, whilst a description of the basic interview protocols can be found in Appendix 3.14 (page 306).

Beginning the interview

In order to ensure careful and truthful answers from students, the researcher established a non-judgmental, and relaxed interviewing environment from the outset, in line with recommended practice (Christensen & James, 2001; Cohen et al., 2007; Mauthner, 1997). After obtaining permission from students for the interviews to be recorded, individuals spent time familiarising themselves with the recording device, in order to demystify the device and to reduce any possible feelings of self-consciousness. This strategy proved successful as, at the close of their interviews, a number of students remarked that they had forgotten about the voice recorder being there.

Having completed the above introductory activity, the worldview interview proceeded with three structured tasks, as described next. An overview of the three tasks has already been provided in Figure 3.5 (page 81).

Task One: Nature collage (Definition of Nature)

The purpose of the first task was to introduce students to the topic of the interview (i.e., Nature) (Cobern, 1991). To begin with, brief clarification was sought concerning students‘ understanding of the terms ―Nature”, ―natural world” and ―natural environment”, and students selected the term they preferred to use during the remainder of the interview. As recommended (Z. Erasmus, personal correspondence, April 25, 2007), the interviewer then set out to locate the concept of Nature within the students‘ own images and experiences of the natural world, before introducing visual and text-based stimuli. To this end, students were asked to close their eyes and imagine a place in Nature, and to describe what they saw there. This visualisation

Table 3.3: Overview of word- and statement prompts used in Part Two and Part Three of the final worldview interview

Aspects of knowing about Nature (based on Cobern, 1993)	Bipolar descriptor pairs	Task Two words	Task Three statements
EPISTEMOLOGICAL DESCRIPTION i.e., Knowing about the natural world			
Knowable: —….all is predictable” —….one can have significant material understanding of events in Nature”	Knowable	Understandable Predictable Orderly	Nature should be studied so that we can learn more about it.
Unknowable: —….Nature is so changeable and random that virtually nothing is predictable” The student is —…clearly more impressed with what is not known than what is”	Unknowable	Confusing Mysterious Complicated It changes	Nature is difficult to understand. There is chaos in Nature.
ONTOLOGICAL DESCRIPTION i.e., What the natural world is like			
Super-naturalistic: —….[the person] clearly believes there to be supernatural involvement in Nature” —….refer to transcendent purpose, [that is] a purpose beyond the level of the material structure/function in the natural world”	Super-naturalistic	Holy Spiritual Powerful	In Nature I see the work of God. Things happen in Nature for a purpose. There is more to Nature than what we can just see and touch.
Naturalistic: —….the belief that material or physical causation provides a sufficient basis for understanding the natural world”	Naturalistic	Can see it and touch it	The natural world is all there is, all there ever was, and all there ever will be.

Table 3.3 (cont...)

Aspects of knowing about Nature (based on Cobern, 1993)	**Bipolar descriptor pairs**	**Task Two words**	**Task Three statements**
EMOTIONAL DESCRIPTION i.e., How one feels about the natural world			
Positive: —…Nature is something beyond the ordinary”; it is benevolent.	Positive	Beautiful Fascinating	I enjoy Nature.
Neutral: —Nature is mundane and prosaic” (Cobern, 1993:946)	Neutral	‗Just there‘ Ordinary	Nature is an everyday part of life that I normally do not think much about.
Negative: Nature is malevolent.	Negative	Frightening	Nature is dangerous.
STATUS DESCRIPTION i.e., What the natural world is like now			
Resource-oriented: Nature is full of resources for mankind to use.	Resource-oriented	Can be used We need it A mixture of different things	Without the things that we get from Nature we could not enjoy the everyday life we have today. I view Nature as something solid, large and reliable.
Conservationist: Nature is endangered and needs to be protected.	Conservationist	Pure Over-used Ruined	I am worried about the pollution and the damage it does to Nature. I believe Nature needs to be protected. Nature can be repaired.

activity was repeated in imagining and describing a second place in Nature.

The natural world might be considered a somewhat abstract and unusual topic for discussion with Grade Sixes, as the concept of Nature currently taught in schools is implicit (Bonnett, 2004). In order to concretise the topic of Nature for the students, as advised by Christensen and James (2001), a visual stimulus was introduced in Task One, in the form of a collage of images of the natural world (Figure 3.7). In line with Cobern‘s (2000b) methodology, the Nature collage was carefully designed to represent diverse aspects of the natural world. The selection of images was validated by two independent researchers. The Nature collage included images of the natural world on macro-levels (e.g., outer space) and micro-levels (e.g., cell), and included both large-scale phenomena (e.g., hurricane cloud) and small-scale phenomena (e.g., bee). There were images from the plant kingdom (e.g., leaf) and the animal kingdom—both wild (e.g., vultures) and domesticated (e.g., cows)—as well as people, and man-made items (e.g., cars). Terrestrial (e.g., in a Nature reserve) and marine environments (e.g., jellyfish) were represented, including conditions that are very cold (e.g. icebergs) and very hot (e.g. desert). The images in the Nature collage also represented aspects of the natural world that might be encountered in everyday life (e.g., banana), unexplored domains in Nature (e.g., astronaut), as well as pre-historic natural phenomena (e.g., fossil) and new life (e.g., egg). Furthermore, there were images representing enjoyable aspects of Nature (e.g., pets) as well as aspects of Nature that might be dangerous and destructive (e.g., volcano).

Figure 3.7: Collage of images used in Task One

The Nature collage was presented to students and they were asked to name which parts they felt were part of Nature, as well as those images that were not part of Nature, and to explain their views. Students were invited to refer to the collage of images at will during the remainder of the interview.

To conclude Task One, a number of questions (Cobern, 2000b) were posed to students in order to elicit possible links between their views of knowing things about the natural world and their views of science, namely:

1. Can we know things about Nature?
2. If so, what kinds of things can we know about Nature, and how do we know about these things?
3. Who finds out these things about Nature?
4. Why do they want to know such things about Nature?

Following on from Task One, two further tasks were employed to elicit discussion beyond what the initial questions and collage of images could accomplish alone (Cobern, 1991, 2000b). Task Two was the focal point of the interview sequence, which was then supplemented by data from Task Three. Students‘ responses to these two tasks provided valuable data from which their views of the natural world could be classified according to a combination of four bipolar descriptor pairs (page 94). Repetition was built into the items in Tasks Two and Three, in order to minimise the potential for insincere comments, to expose any apparent contradictions within the students‘ views, and to address the possibility of students editing their answers while being interviewed. This internal consistency check, as recommended by Christensen and James (2001), Cohen et al. (2007) and Kvale (1996), was employed to improve the reliability and trustworthiness of the data.

Task Two: Word Sort

Task Two consisted of a set of 22 words (Figure 3.5, page 81) that were shown to students in random sequence, and which students then divided into two groups, namely, *Nature* is or *Nature is not*. As recommended by Cohen et al. (2007), a middle/undecided group was also allowed, in order to accommodate students who did not know all the answers. Whilst students allocated each word to a group, they were asked to share their reasoning and/or describe an example to explain their view. This think-aloud procedure was employed in order to address possible problems arising from students‘ limited language abilities, as advised by Christensen and James (2001) and Cohen et al. (2007). For example, where students were uncertain of the meaning of a word, it became necessary for them to seek clarification thereof, and consequently, words that were unfamiliar to students could be explained. Moreover, students‘ use of a particular word could be probed further in response to the explanation/illustration they provided, as advised by Christensen and James (2001). The think-aloud procedure further helped to eliminate the possibility of acquiescence bias mentioned by Christensen and James (2001) and Cohen et al. (2007), as students needed to elaborate on their responses by drawing on specific examples to illustrate their views.

After sorting all of the Task Two word prompts into groups, the words in each group (e.g., *Nature is*) were then organised into sub-groups, depending on how the student viewed the relationships between the various concepts about Nature. The student could choose to leave some words on their own. Students then selected the sub-group of words they would discuss first if describing the natural world to someone. They were asked to describe why they chose that particular group of words to talk about first, and to explain why those words had been grouped together. This procedure was repeated for all the remaining sub-groups. In line with recommendations made by Kvale (1996) and Cohen et al. (2007), the researcher remained alert for contradictions and ambiguities in the students‘ responses throughout the word sorting and sub-grouping activity. Task Two was concluded by pasting the word prompts onto paper, arranged in their sub-groups, and numbered in order. These data sheets were referred to later when transcribing and analysing the interview data.

Task Three: Statement Sort (and Dyad Comparison/Rank)

During Task Three, students built on their experience of the familiar *Nature is/Nature is not* activity completed during the previous task, whilst the new ranking activity introduced variation into the interview process in order to retain students‘ attention and interest. The purpose of Task Three was twofold. First, due to the repetition built into the task items (Table 3.3, page 86), Task Three provided opportunity for confirmation of the beliefs elicited in Task Two. Second, the ranking of the statements (i.e., dyad comparison) provided insights into the relative importance of the students‘ beliefs about Nature and how their various beliefs were connected. These data, concerning the relationships between the various views that students described about Nature, were used in compiling a concept map of each student‘s view of Nature, as described later (page 95).

Task Three consisted of 15 statements relating to Nature (Figure 3.5, page 81) that were shown to the student in random sequence. Students divided the statements into two groups, depending on whether they agreed (*Yes/Agree)* or disagreed (*No/Disagree*) with each statement. Where necessary, a middle/undecided group was created. As students allocated each statement to a group, they were asked to explain their reasoning and/or describe an example to illustrate their view. All of the statements in each group (e.g., *Yes/Agree*) were then mixed together and two statements were selected randomly. The student was asked to choose one statement to retain and one to be replaced by a third randomly drawn statement until all the *Yes/Agree* statements had been compared. This was essentially a ranking task with the last sentence chosen being ranked first. Statements that were retained for three or more comparisons were marked with an asterisk as important views. This procedure was repeated for all statements. To conclude Task Three, the statements were pasted onto paper in their various subgroups, and according to their rank, for future reference.

Concluding the interview

Before ending the worldview interview, students were invited to raise queries or to make any additional comments. Furthermore, in order to keep students fully informed regarding the remaining research process and their participation therein, as recommended by Cohen et. al. (2007), at the end of each worldview interview, the researcher explained the procedure to be followed in the days ahead. That is, interview transcripts were transcribed and analysed, and a descriptive narrative (‗Nature story‘) was composed for each student and then presented to them during a short follow-up interview. Details of the follow-up interviews are provided later (page 95).

Additional comments regarding venues, and peer contamination of responses

The venues used for conducting the worldview interviews were the same as those used when administering the *VNOS-rs* questionnaire (page 77) and when conducting the follow-up interviews. The students were therefore familiar with these venues, and felt comfortable and relaxed during their subsequent meetings with the researcher there.

Due to the nature of the data collection procedure (i.e., students met with the researcher on three separate occasions, during the course of a week), there existed the possibility that students might discuss amongst themselves their meetings with the researcher, and that this, in turn, might compromise the reliability or validity of the data. However, the results concerning the students‘ views of the natural world revealed no significant peer contamination of their responses. This claim is supported by the finding that the students were unaware of (but curious to know) the activities their peers had completed with the researcher during the worldview interviews, and in some cases, students wondered how their peers had responded to particular worldview tasks. It was considered that the students would not have made such inquiries if they had been discussing, amongst themselves, the details of their worldview interviews.

Analysis of data concerning students' views of the natural world (i.e., Nature)

The students‘ views of the natural world—elicited by means of the worldview interview described above—were analysed in a number of steps, namely: audio recording and transcription of the interview, coding the interview transcripts, and creating a concept map and composing a descriptive narrative. Two or three days after the worldview interviews, follow-up interviews were conducted with the students. The recorded follow-up interviews were also then transcribed and coded, in order to finalise the analysis of each students‘ views of Nature and to create a worldview profile for each case. Each of these steps in the data analysis procedure will now be described in turn.

Recording the interviews

In order to ensure good clarity of the interview recordings (Cohen et al., 2007; Poland, 2001), the worldview interviews were recorded by means of a high quality digital audio recorder. The device was placed on a stable surface in front of the student, in a quiet venue, as recommended by Cohen et al. (2007) and Poland (2001). As previously mentioned (page 85), students granted permission for their interviews to be recorded, and care was taken to familiarise each student with the recording equipment at the beginning of the interview, so that the device was unobtrusive.

Transcription

Each worldview interview and follow-up interview was transcribed in its entirety, verbatim. In each case, the transcription was completed on the same day that the interview was conducted, in order to be able to recall the details of the dialogue, as advised by Cohen et al. (2007) and Poland (2001). Field notes and records collected during the interview tasks (i.e., Tasks Two and Three) were used when reviewing each transcript. All of the transcribing was done by the interviewer/researcher and thus, in accordance with recommendations made by Cohen et al. (2007), a uniform style was used. The transcription notation system is given in Appendix 3.15 (page 311). Furthermore, the transcript of Dyllan‘s worldview interview is provided in Appendix 3.16 (page 313). This interview transcript is not intended to foreshadow the results, but rather as an example to show how the transcriptions were done, in order to illustrate the analytic procedures that were employed as part of the research methodology of this study.

Coding the interview transcripts

In line with the recommendations of Miles and Hubermann (1994) and Richards (2005), segments of meaning from the transcript texts were assigned codes. Appendix 3.17 (page 333) presents the worldview codes that were employed in the present study. It is recommended that an interview transcript be coded on two separate occasions in order to enable the cross-checking of coding (Richards (2005). Thus, codes were first assigned manually to the transcript texts (i.e., pencil and paper method). Each transcript was then coded separately on a second occasion (i.e., when inputting the data onto the computer), and the codes were double-checked.

Due to the structured nature of the worldview interview sequence, many of the codes were pre-existing, that is, a number of the analytic codes were derived from the contents of the prompts employed during Tasks One and Two. However, during the coding process, additional codes emerged from the data (e.g., *Cycle*, *Mistakes*, *Nature as a being*, *No function/purpose*, *Delicious*, *Boring*). In line with the recommendations of Coffey and Atkinson (1996) and Lincoln and Guba (1985), some of the additional codes arose more or less directly from the students' words. Consistency in assigning codes to the text was achieved by developing a definition for each code, as discussed by Richards (2005).

Refinement of the code definitions demanded a close reading and a deep understanding of the meaning of each code, in order to understand the relationships between the various codes. For example, the codes *Nature kills* and *Dangerous* referred to the potential harm that arises *from* Nature, whilst the codes *Man kills*, *Endangered* and *Polluted*, referred to the potential harm that people can do *to* Nature. Also, with regard to the code *Purpose*, in some cases, students referred to purpose in a super-naturalistic way, whilst other students described causes and purposes in Nature that are materialistic and naturalistic. This particular code was therefore renamed so that it could relate to both Super-naturalistic (i.e., *Purpose transcendental)* and Naturalistic (i.e., *Purpose physical*) worldview descriptions. As such, the refinement of the codes prompted a closer scrutiny of the descriptor categories to which the original interview prompts (words and statements) had initially been allocated, and a number of prompts were re-allocated as a result (page 84). To this end, an additional emotional descriptor was also created (i.e., Negative) in order to accommodate responses that were neither Positive nor Neutral (e.g., *Frightening*) (page 84).

One of the decisions that has to be made when coding, is how finely to specify the codes (Richards, 2005). For example, the following views all related to the concept of Nature being knowable: we *do* know things about Nature, we *can* know things…, we *need to know*…, we *should* know…, and *we can figure it out*. In order to avoid creating an unnecessarily large set of codes, all of these subtle variations were included in the definition for a single code (i.e., *Know/learn*). By way of a second example, various references relating to *money*, *business*, items being *expensive*, *buying* things, and things being *rare*, were all included in a single code, namely, *Valuable*. However, some subtle distinctions in meaning were worth representing in separate codes. For example, statements referring to things being killed in Nature were detailed separately as examples where *Man kills* (Conservationist) as distinct from contexts where

Nature kills (Negative). Likewise, references to people using Nature included statements that people *can* use it…, we *do* use it…, and we *need to* use it—these statements were assigned the code *Useful* (Resource-oriented). These statements were distinguished from views that people *use [Nature] too much*—in other words, Nature is *over-used* (Conservationist).

Assigning each code to a worldview descriptor (i.e., Knowable or Unknowable views) constituted a second level of coding, that is, grouping codes into smaller sets, as described by Miles and Huberman (1994). Table 3.4 provides three examples of this second level of coding that was carried out.

Table 3.4: Examples of first- and second-level coding of the worldview interview transcripts

First-level coding Code label	Code definition	**Second-level coding** Bipolar descriptor	Worldview description
Technology level	Our technology is not advanced enough to find out more.	Unknowable	Epistemological
Other world	There was another world before/after this (e.g., After-life), including references to the Day of Judgment.	Super-naturalistic	Ontological
Helpful	Nature impacts on people in a positive way. Nature helps and heals.	Positive	Emotional

Further to the above two levels of coding, an additional coding procedure was completed for each interview transcript, which involved noting the specific examples and contexts students cited when explaining their ideas about the natural world. Noting students' particular examples served multiple purposes. First, whilst coding, these specific examples were drawn upon in order to finalise the allocation of a few undecided codes to the relevant bipolar descriptor. For example, descriptions of Nature as a *Mixture of different things* indicated views that were resource-oriented in some cases (i.e., concerning various natural resources available for people to use), and unknowable in others (i.e., regarding diversity in Nature). Second, when creating the concept map for each student, references to a single illustration/example helped in the identification of links between the various ideas and concepts constituting a student's views of Nature. For example, one student's various references to hurricanes illustrated her view that Nature is dangerous (Negative), and unpredictable and chaotic (Unknowable)

To summarise concerning the analysis of the interview data, the practice of coding the transcripts was completed on two levels, and it was undertaken in three stages. First, codes were assigned to meaningful portions of the text, both manually and on computer (i.e., level one coding). Second, specific examples cited by the student were noted. Third, each code was assigned to a worldview descriptor (i.e., level two coding).

Concept map and Descriptive narrative (‗Nature story')

Having coded each interview transcript as detailed above, these analyses, combined with the original data sheets collected during the interviews (i.e., from Tasks Two and Three) were analysed in order to establish links between the various statements and explanations articulated by the student. These links were depicted in the form of a concept map (Appendix 3.18, page 343). The concept map was essentially employed as an analytic tool that enabled the researcher to compose an individual worldview narrative (‗Nature story') for each case (Appendix 3.19, page 344). These narratives were later used to compile an overall worldview profile for each case (page 97), and in analysing coherence within students' views of the natural world, as well as in analysing coherence between students' views of Nature and their views of NOS (Chapter 4, page 180). As far as possible, therefore, the students' own words and examples were used when compiling their narratives. The accuracy of each student's narrative was verified during a follow-up interview, as described next.

Follow-up interviews

In line with recommendations made by Kvale (1996), a semi-structured, individual follow-up interview was conducted with each student in order to clarify, supplement, and adjust the initial analyses of their views of the natural world. To begin with, the student's worldview narrative was read aloud. Students enjoyed listening to their own ‗Nature story'. They listened carefully and, as advised by Cohen et al. (2007), students were invited to interrupt the reading at any time, in order to point out any errors or to add anything more to their narrative account. This was done in order to ensure that each narrative accurately portrayed the student's view of the natural world, in line with recommendations made by Creswell (2008) and Lincoln and Guba (1985).

In a number of cases, students pointed out changes and additions they wished to be made, which indicated that they were indeed listening actively. That said, however, the adjustments students noted were typically minor. For example, Dyllan asked that ―mom" be changed to ―ma" (Appendix 3.19, page 344: line 24) in the final paragraph of his narrative. Aaeesha asked that the word ―nice" (i.e., my garden smells…) be changed to ―delicious". Gideon asked to change his statement that plants are not dangerous (citing the example of Venus Fly Traps to support this view). Indeed, students were typically surprised and amazed at the accuracy with which their views had been encapsulated in their worldview narratives. Dyllan, for example, remarked, ―Ah! How did you know all that, m‘am?”, and others described their ‗Nature story‘ as being ―perfect”.

After verifying the accuracy of the students‘ worldview narrative with them, a number of additional questions were then posed to students in order to clarify and/or confirm, where necessary, some of their statements from the initial worldview interview. The researcher probed for additional examples and further explanations, and collected confirmatory data to finalise the categorisation of each student‘s views according to the various bipolar descriptor pairs (page 94). The follow-up interviews were transcribed verbatim on the same day as the interviews were conducted, and the transcripts were then coded, as described in the previous section.

Verification of data analyses

In addition to using the worldview narrative as a means of verifying the researcher‘s interpretation of each student‘s views of the natural world, data for three cases were sent to two independent researchers in science education, who are involved in research relating to worldviews and views of Nature. The verification process was conducted in two phases, namely, coding the worldview interview transcripts, and then categorising the students' overall views of Nature in terms of four bipolar worldview descriptors.

In accordance with Richards (2005) and Miles and Hubermann (1994), the independent researchers were asked to read clean copies of the three worldview interview transcripts (specifically, the first ten pages thereof) and to assign codes thereto, by using the codes and code definitions provided to them (Appendix 3.17 [page 333]). Whilst coding the transcripts, the researchers were also asked to reflect upon and comment on the precision and clarity of the code definitions, and to comment on how closely the codes fitted the data.

In addition to validating the coding of sample interview transcripts, input was sought regarding the overall categorisation of students‘ views of the natural world (i.e., with regard to each of the four bipolar descriptor pairs). To this end, the two independent researchers were provided with a summary document for each of three cases, which contained extracts from students‘ narratives, organised according to each of the four worldview descriptions (e.g., epistemological, ontological, emotional and status descriptions). For each case, the reviewers were asked to check whether the statements were related to the particular description under which they had been organised (e.g., epistemological descriptions: knowable and unknowable statements), and, more importantly, to classify each student‘s overall views according to particular bipolar descriptors (e.g., Knowable, Naturalistic, Positive, and conservationist [Maya]). Overall, there was found to be an agreement of 75% and 83% in the outcomes of the two researchers‘ overall classification of the students‘ views of the natural world.

Further analysis of the students’ of the natural world: Individual worldview profiles

In order to facilitate a cross-case comparison of the views of Nature described by the fourteen cases being studied, and for the purposes of analysing the coherence of students‘ views (page 97), a synopsis of each case was compiled in the form of an individual worldview profile (Chapter 4, page 161). To this end, statements relating to each of the four worldview descriptions (e.g., epistemological descriptions: knowable and unknowable statements) were extracted from the students‘ worldview narratives, and then categorised overall in terms of a combination of various descriptors. For example, Dyllan‘s view of Nature was classified as Knowable/Unknowable, Naturalistic, Negative, and Conservationist.

Having collected rich and detailed data concerning the students‘ views of NOS and their views of the natural world, and verified the analyses of these data (as described above), the researcher could then proceed with the analysis of coherence of the students‘ views, as explained next.

Analysis of coherence

The main research question of the present study concerned the coherence of the Grade Six students‘ views of NOS and their views of the natural world. To this end, Thagard‘s (1989, 1994) theory of explanatory coherence was drawn upon (Chapter 2, page 48) in order to analyse the coherence within the students‘ views of NOS and their views of the natural world, to analyse the coherence between these two domains, and, finally, to determine the overall coherence of the students‘ views. In this section, the application of the principles of explanatory coherence is explained, followed by a description of how various coherence analyses were conducted.

Overview of application of explanatory coherence principles

Thagard (1989, 1992, 1994, 2006) proposes a number of principles of explanatory coherence that make it possible to establish relations of explanatory coherence within the conceptual framework (or explanatory system) of an individual. An explanatory system consists of various concepts, theories, or ‗hypotheses‘ that individuals encounter, for example, in science. In the context of the present study, such concepts were taken to refer to the Grade Six students‘ views about NOS and their ideas about the natural world. Thagard (1989) refers to the relationship between two concepts within the explanatory system as coherence. Concepts cohere when they agree with one another and they are incoherent when they resist holding together. Each of the coherence principles applied in the present study will now be described in turn, and illustrated by means of extracts from the views of Dyllan. It is important to note that the first four principles pertained to coherence *between* students' views of NOS and their views of the natural world, whereas the fifth principle (system in/coherence) pertained to coherence *within* each of these two sets of views (i.e., coherence within a student's views of NOS or within her/his views of Nature).

Principle 1: Symmetry (Agreement)

The explanatory coherence of symmetry concerns a symmetrical relationship between two concepts, that is, when two concepts ―cohere with each other equally" (Thagard, 2006:142). In the present study, the principle of symmetry was applied when a student's statement about NOS was coherent with (i.e., agreed with or supported) her/his statement about the natural world. Similarly, when a student's statement about Nature was coherent with her/his statement about NOS, the two views were considered to be symmetrical. In the case of Dyllan, the principle of symmetry was applied to his view that people can find out things about Nature, and that this was interesting for him.

> *NOS statement:*
> …If scientists say…there's a hundred billion galaxies, then it will be on the news, or it would be on the Internet as a **interesting fact**… (NOS statement)
>
> *Statement about Nature:*
> It is **interesting to find out facts** about Nature, like, with the diamond, I didn't know that the Earth moves and that's how we get diamonds, but it doesn't happen often. That's **fascinating** for me.

Principle 2: Contradiction (conflict/disagreement)—the converse of Principle 1

The second principle, contradiction, concerns contradictory concepts that are incoherent with one another (Thagard, 1989, 2006). In the present study, the principle of contradiction was applied when a student's statement about NOS conflicted with her/his statement about the natural world, or vice versa. In other words, the two statements were contradictory and therefore incoherent. In the case of Dyllan, the principle of contradiction was applied to his view that scientists' knowledge is based on direct experiences of phenomena in Nature or by archaeologists finding fossils. However, as no people were alive during pre-historic times, Dyllan was unsure of how scientists know about dinosaurs.

> *Statement about Nature:*
> We can **find out** things about nature from…we can **experience** it ourselves…or they are **an archaeologist that found fossils**.
>
> *NOS statements:*
> [Re: scientists' knowledge of dinosaurs] I don't know how they **knew**…Nobody really lived back then.

> It is very difficult to say how scientists know how dinosaurs look like, because **they weren't there**.
>
> I have heard people say that there was no food so the dinosaurs died. And I heard a volcano killed the dinosaurs. But **no-one was alive then so it was difficult to give a right answer**.

Principle 3: Explanation (Illustration)

Explanation, the third principle of explanatory coherence, pertains to a concept that is coherent with that which it explains, and/or to an explanation that supports another concept (Thagard, 1989, 2006). For example, in the present study, the principle of explanation was applied when an *example* or *illustration* cited in a student‘s statement about NOS was coherent with a statement concerning her/his view of the natural world. Similarly, this principle was applied to instances in which the student‘s statement about Nature contained an *example* or an *illustration* that supported or agreed with her/his statement about NOS. In Dyllan‘s case, the principle of explanation was applied to his view that there are some things in Nature that cannot be explained (e.g., his dog‘s recurring ear infection), and that scientists disagree if they do not have enough facts.

> *NOS statement:*
> [Scientists sometimes disagree because] they **don't have enough facts**.
>
> *Statement about Nature:*
> …Sometimes I wonder, with my dog, he just does this weird stuff and **there's no real answer**…He‘s got an ear problem, so we keep cleaning out his ear and we take him to the doctor and then his ear is fine again, but afterwards his ear is funny again. It goes on like that forever, so it‘s confusing to me. **There is some stuff in nature that we can't give an explanation for**.

Principle 4: Competition (conflicting explanations)—the converse of Principle 3

Two statements are considered to be in competition with one another if they are ―not explanatorily connected" (i.e., one does not explain the other) (Thagard, 2006:142). For example, in the present study, the principle of competition was applied when an *example* or an *illustration* in a student‘s statement about NOS conflicted with her/his statement about the natural world. Similarly, the principle of competition was applied when an *example* or an *illustration* in the student‘s statement about Nature conflicted with a statement in her/his NOS view. In Dyllan‘s case, the principle of competition was applied to his view that scientists have collected evidence from outer space (for example, by means of exploration and recorded images). Yet Dyllan did not trust what scientists say and he thought that what scientists tell people could be incorrect.

> *NOS statement:*
> **Voyager 1 that was sent out** so they can experience our solar system…They **took a picture of the Milky Way** galaxy how it looks in space… (NOS).

Statement about Nature:
Our teacher says in science that **scientists say** the sun is going to blow up or it is going to fall into itself, or the Earth is going through the same thing, but in one billion years……**I don't trust what they tell us**…I don't believe the scientists. They are not super-humans. **They also make mistakes, so maybe they're wrong**…

Principle 5: System Coherence or Incoherence

According to Thagard (2006), the acceptability of a concept within an explanatory system depends on its coherence with other concepts within that system. As such, the fifth principle of explanatory coherence, system incoherence, is concerned with the coherence *within* a particular conceptual framework (e.g., views of NOS, or views of the natural world), as opposed to the coherence *between* two domains (i.e., between views of NOS and of Nature). In the present study, therefore, the principle of system in/coherence was applied in evaluating how each of the ideas comprising a students' NOS views were coherent with her/his overall NOS view, as well as in evaluating how each of the students' ideas about the natural world were coherent with her/his overall view of Nature. That is, where there were conflicts within a students' view of NOS, these were regarded as instances of system incoherence. By way of illustration, the following extracts demonstrate an example of system incoherence that was found within Dyllan's NOS view. That is, Dyllan described how scientists sent out Voyager 1 and Voyager 2 to experience the solar system, and to take pictures of outer space.

Voyager 1 that was sent out so they can experience our solar system…

They sent **pictures**, they sent, like, a **Voyager** out to space and… that took pictures of space, so **that would give them idea of what it was like**.

Yet Dyllan claimed that scientists report inaccurate findings.

Say the Voyager 1 passed Pluto and now it's shut down, it's not getting any sunlight and now it's travelling for a long time and there's a planet that looks similar to Pluto or maybe **has the same structure as Pluto** and now they get sunlight again and they say, ―Ah it's just past Pluto, and it receives light from somewhere else." **But it's not Pluto**. It's like a different planet. Something like that.

Moreover, Dyllan was unsure of whether scientists study outer space.

…**Space is Nature because it always was there, but they don't really study- they don't work with that**, m'am, because they can't touch the planets, do you know what I mean, m'am?

Additional principle: System Complexity—derived from System incoherence

Further to applying the principle of system incoherence in analyzing coherence within the students' views, careful analysis revealed that, in some cases, there were complexities or inconsistencies within a student's views that were not strongly opposed enough to be termed system incoherence. An additional principle—derived from the principle of system incoherence—was therefore developed, namely, system complexity**.** For example, instances of system complexity were found within Dyllan‘s views of the natural world, specifically in regard to his epistemological and ontological worldview descriptions. That is, within Dyllan‘s epistemological worldview description, he said that Nature is confusing but partly understandable, in that it is complicated and strange.

> There are things that happen in Nature that‘s quite **strange**, like the desert. How did all that sand get there? It‘s not simple and ordinary, like you see a whole place full of sand and it‘s quite **strange** to see. And when I look at a jellyfish, I just see this thing, and it looks quite **strange**, and all the animals look quite **strange** because they all play different parts in their lives. Every animal has a different role, like the bee gets honey from a flower and he puts it in the hive. A cow eats and then he gives us milk…

Dyllan also stated that there are some things in the natural world that cannot be explained.

> And sometimes I wonder, with my dog, he just does this weird stuff and **there's no real answer**. Sometimes he just digs holes in the ground even if he has no bone. I don‘t understand that. And he‘s got an ear problem, so we keep cleaning out his ear and we take him to the doctor and then his ear is fine again, but afterwards his ear is funny again. It goes on like that forever, so it‘s confusing to me. **There is some stuff in Nature that we can't give an explanation for.**

However, Dyllan also described that there is some order in Nature, and that future events are predictable.

> In Nature, **we can tell what's going to happen in the future**, like people say that in 2012 there‘ll be another eclipse where Venus will come over the sun. They say the next time that will happen is like in the thousands of years‘ time, so **there must be some order in nature**. **There is like a cycle in Nature**. For example, the cows eat lots of grass, then their tummies get big then they can give us milk. Then we drink the milk to stay healthy so we can still feed them.

A second example of system complexity within Dyllan‘s view of the natural world, was found within his ontological worldview description. That is, Dyllan described a largely naturalistic view of Nature.

> All food is **created by Nature**.
>
> Nature is things that man didn‘t make. It has just **been there all the time**, like, before we were born… I think that there was **no beginning** to Nature, and it **will always be there**, like, the planets.
>
> But it is **not spiritual** in the sense of people sacrificing cows, playing drums and singing songs. It is *holy* in the way that animals like vultures look up to the lions and they don‘t attack them. It‘s, like, who is number one in the jungle and controlling.

Nonetheless, Dyllan chose to prioritise his religious beliefs over what he had been taught in science lessons at school.

> Our **teacher** says in **science** that **scientists say** the sun is going to blow up or it is going to fall into itself, or the Earth is going through the same thing, but in one billion years. That‘s quite a long time. But I don‘t trust what they tell us, because when I go to **church**, they sing a hymn where the last line says, ―world without end" and it goes ―Amen". So I think if **God** says there will be no end, I think that‘s right. **I don't believe the scientists.** They are not super-humans. They also make mistakes, so maybe they‘re wrong about the world ending.

The next section provides an explanation of how the analyses of coherence were conducted for the fourteen students that were studied in-depth.

Procedures for analyzing coherence of students' views of NOS and their views of the natural world

As previously mentioned (page 97), coherence analyses were concerned with the relationship between the students' views of NOS and their views of the natural world, as well as examining the internal consistency of each set of views. The various procedures for carrying out the coherence analyses are summarized in Figure 3.8, and explained in detail thereafter.

In order to analyse coherence *between* the students' views of NOS and their views of the natural world, four principles of explanatory coherence were applied, namely, symmetry, contradiction, explanation and competition. To begin with, these four principles were applied in order to analyse coherence between the students' definitions of the natural world and their views concerning the nature of scientists' work. These four principles were then further applied in order to identify coherent and incoherent links between students' statements relating to each of the five aspects of NOS (i.e., tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative/creative aspects) and each of the four worldview descriptions (i.e., epistemological, ontological, emotional, and status descriptions). Amongst the various coherent and incoherent links that were established, a number of themes were identified. Links were then examined between these various themes and particular levels of NOS understanding. These analyses were conducted in order to identify issues that science teachers need to be address in order to improve students' understandings of NOS.

Further to analyzing coherence between students' views, analyses were conducted concerning coherence *within* the students' views of NOS and *within* their views of the natural world. To this end, the explanatory principle of system incoherence was applied, as well as an additional principle (derived from the principle of system incoherence), namely, system complexity. Themes were identified amongst the various instances of system complexity and system incoherence, and from these themes, further issues could be identified that need to be addressed in science classrooms.

Overall coherence of the students' views was determined by analyzing the proportion of incoherent links that existed *between* students' views of NOS and their views of Nature, as well as by considering the various instances of internal consistency that were identified *within* students' views relating to each of the two domains.

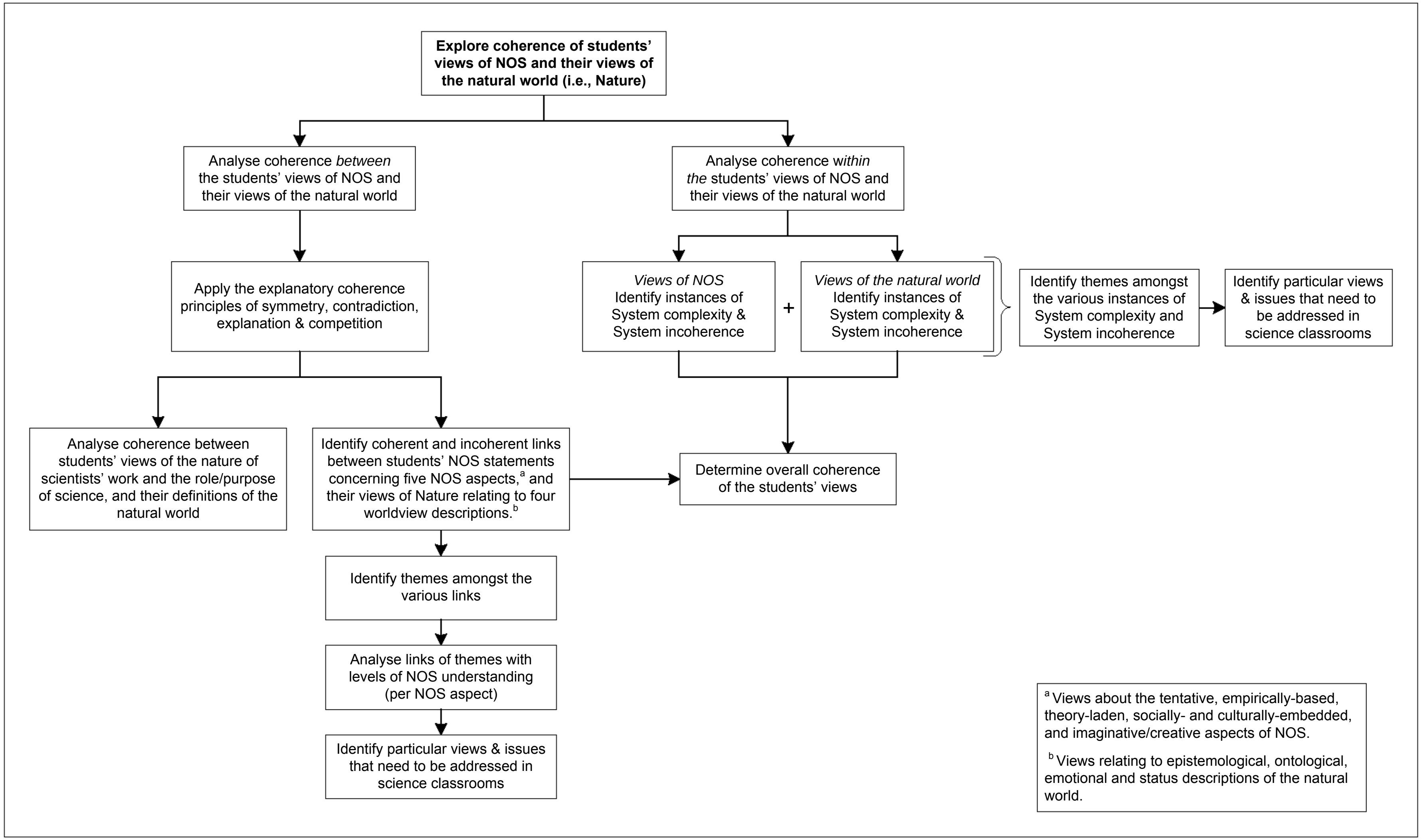


Figure 3.8: Diagrammatic overview of the procedures for analysing coherence of the students' views of NOS and their views of the natural world

To recap concerning coherence, the present study drew upon a number of principles of explanatory coherence (Thagard, 1989, 1992, 1994, 2006) in order to explore the coherence of the Grade Six students' views. Coherence *between* the students' views of NOS and their views of the natural world was analysed by applying the explanatory coherence principles of symmetry, contradiction, explanation and contradiction. Coherence *within* the students' views was analysed by applying the principles of system complexity and system incoherence. Overall coherence of the students' views was then determined by considering the incoherent links between their views as well as the instances of system complexity and system incoherence within their views.

Chapter summary

A qualitative research design was employed in this exploratory study in order to collect rich data concerning students' views of NOS and their views of the natural world. Participants were purposively selected in order to maximise the diversity of views of the natural world represented by the students, whilst also controlling for a number of other factors that might impact on the students' views of NOS. Evidence of the religious affiliation and the science—and NOS—teaching at each school was collected by means of semi-structured interviews. Written questionnaires were administered to the students in order to record details of their personal background information, and in order to elicit student' views of NOS. Structured interviews were then conducted with the students in order to elicit their views of the natural world, and thereafter, semi-structured follow-up interviews were conducted. Coherence analyses were carried out after these various data had been analysed and verified. Analyses of coherence between students' views of NOS and their views of Nature were conducted by applying explanatory coherence principles of symmetry, contradiction, explanation and competition, whilst the principles of system complexity and system incoherence were applied in order to analyse coherence within the students' views of each domain. Thereafter, the overall coherence of students' views could be determined.

Chapter Four, which follows next, presents the results collected by means of the various data collection—and analysis—procedures that have been described here.

Chapter Four

RESULTS

The aim of this study was to elicit the views of a sample of Grade Six students in regard to the NOS and the natural world, and to examine the coherence between these two sets of views. Fourteen cases were purposively selected for in-depth study. This selection strategy was designed to maximise the diversity of worldviews represented by the students, whilst also taking into account other possible factors (besides worldview)—such as, for example, age, cultural background, socio-economic status, and the nature of science teaching at school—that might influence their NOS views (Chapter 3, page 57). NOS data were collected by administering open-ended, written questionnaires, accompanied by an immediate review process as well as semi-structured follow-up interviews. The students' levels of understanding relating to each of the five NOS aspects (i.e., tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative and creative aspects) were analysed by means of an analytic framework that was developed from international reform and curriculum documents (Chapter 3, page 78). Worldview data were collected by conducting structured, activity-based interviews and semi-structured follow-up interviews. These data were analysed in relation to four worldview descriptions (i.e., epistemological, ontological, emotional and status descriptions) by means of a procedure that involved the coding of interview transcripts, followed by the creation of a concept map, and by finally compiling a worldview narrative for each case (Chapter 3, page 92). Coherence between the students' worldviews and NOS views was examined by employing various principles of Thagard's (1989, 1992, 1994, 2006) explanatory coherence theory (i.e., Symmetry, Contradiction, Explanation, Competition, System complexity and System incoherence) (Chapter 3, page 97). In this chapter, the results are presented in regard to the students' views of the nature of science (NOS) (Part 1), their views of the natural world (i.e., Nature) (Part 2), and coherence between these two domains (Part 3).

Part 1: Views of the nature of science (NOS)

In examining the students' views of the nature of science (NOS), their responses were analysed in regard to the kinds of work that scientists do and the role/purpose of science and, specifically, their views regarding the tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative/creative aspects of NOS. This was necessary in order to determine the levels of understanding the students held regarding each of these five NOS aspects. A comparison between individual students' NOS profiles was then made, and the overall coherence of the students' NOS views was determined.

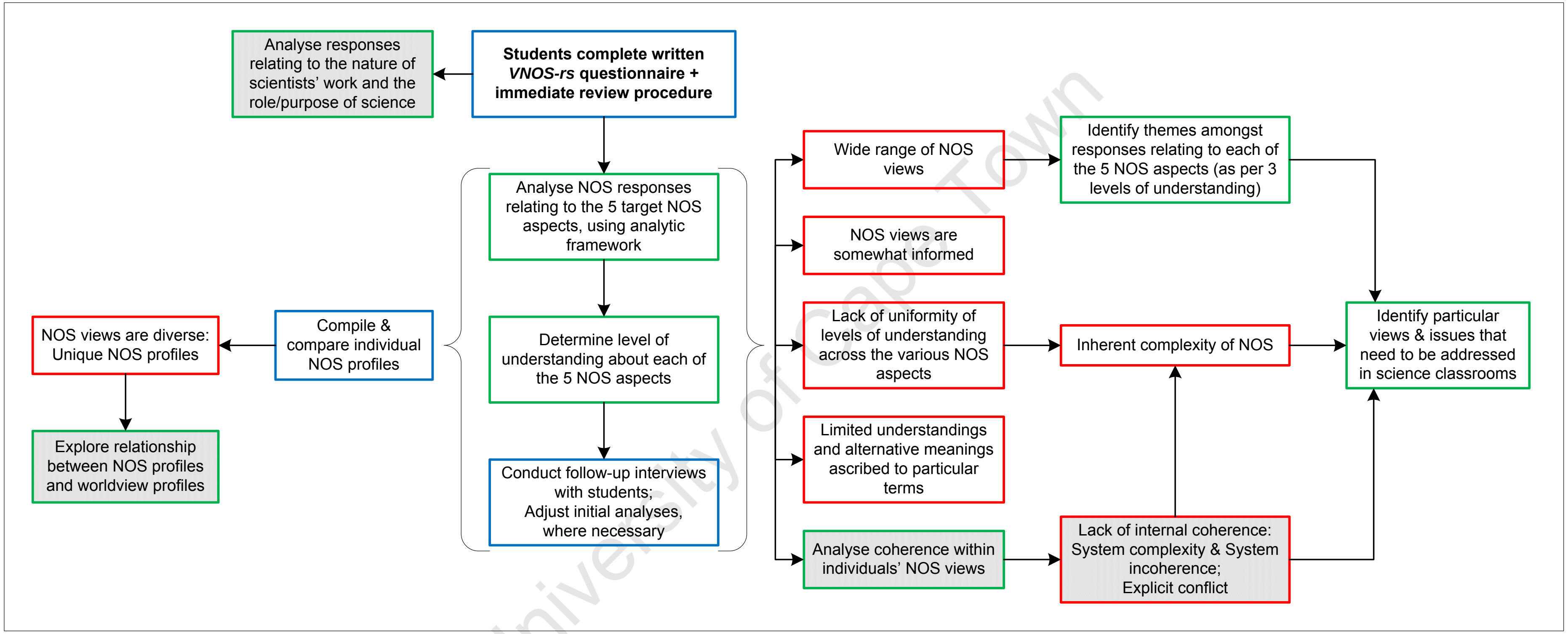
In this section (Part 1), results are presented regarding the students' views of the nature of science with respect to (1) the kinds of work that scientists do and the role/purpose of science, (2) the range of views students' described pertaining to each NOS aspect, (3) the richness of individuals' NOS views, (4) the diversity amongst the NOS profiles of individual cases, (5) the students' overall levels of understanding about NOS, (6) the internal coherence within the students' NOS responses, as well as (7) explicit conflict between science knowledge presented to students at school and at home. Figure 4.1 presents a diagrammatic overview of the NOS data that were collected and analysed, and the findings that such analyses yielded.

The nature of scientists' work, and the role/purpose of science

Students' images of scientists and the work they do, including their views of the role/purpose of science, can provide insights into students' epistemological views about science (i.e., their views of NOS, or the nature of scientific knowledge and how it is developed). One of the foci of the present study was on the students' views of NOS, specifically in regard to the tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative and creative aspects of NOS. However, in addition to eliciting the students' views about these five NOS aspects, the students were invited to describe their views about the role/purpose of science and the kinds of work that scientists do, in the first three items in the *VNOS-rs* questionnaire (i.e., Questions 1 a,b,c [page 292]). These items were included to introduce the topic of science. Moreover, it was considered that the students' responses to these introductory items might be related to their views of the natural world. For example, scientists study the weather (which may or may not be viewed as predictable) in order to find out more (Un/Knowable) and to develop the world (Resource-oriented). As such, it was considered that the students' responses to these introductory questions might provide insights into the relationships between their NOS views and their worldviews, where exploring coherence between the students' NOS views and worldviews constituted the main focus of this study. Such links were indeed identified, as will be presented in Part 3 (Coherence) of this chapter (page 180).

The kinds of work that scientists do

According to the students in this study, scientists are involved in a variety of kinds of work. The most common responses amongst the students included views that scientists do experiments and work with chemicals (Aamir, Brian, Dan, Dyllan, Reza, Victoria) and that they try new inventions and create new things (Aamir, Brian, Raashid, Victoria). Students also described scientists studying Nature such as plants and animals, the environment, and the weather (Maya, Shafia, Victoria, Yamina), as well as studying space (Brian, Dyllan, Maya) and things from historical times (Brian, Dyllan, Reza). Less common views included responses that



KEY: Blocks outlined in blue indicate data that were collected, blocks outlined in green indicate analyses that were conducted, and blocks outlined in red indicate results of the various analyses; Blocks shaded in *grey* signal analyses and results relating to *coherence* (these aspects are therefore also reflected in Figure 4.17 [page 179]).

Figure 4.1: Diagrammatic overview of the data collected concerning the students' NOS views, analyses that were conducted, and the results that these analyses yielded

scientists discover things (Raashid, Samuel), and that they find cures for illnesses (Brian, Victoria). Scientists also work with technology (Dyllan). Moreover, it was not uncommon for individuals to describe more than one type of work that they believe scientists do.

The following extracts illustrate the varieties of kinds of scientists‘ work identified by students:

> It depends on what sort of science…They discover history (i.e., archaeologists) or look deep into space (i.e., planets), try new inventions (i.e., robots), try new experiments (i.e., medicine), and find cures for illnesses. (Brian)
>
> Invent things, work with chemicals, study Nature, find cures to things…There are all different types of scientists, like archeologists (they dig), biologists (look at the environment), geographers (look at the world and cities), and meteorologists (they study more of the weather). They all study different types of things and so they all do different things. (Victoria)
>
> They study different things...e.g. Animals, humans. They do research. They‘re looking under a microscope at the bones. Science is mostly studying plants and animals. (Yamina)
>
> Scientists are people who find out things about space and old people that used to live on Earth. (Dyllan)
>
> They discover experiments and some work with electricity, e.g., Cartoon Network. (Dan)
>
> They create and test stuff. They improve technology in the modern world. It also depends what section they do in science…They discover stuff that hasn‘t been discovered yet, and they discover history and create new things. (Raashid)

Significantly, a number of the students stated explicitly that the study of science includes a variety of fields of study:

> It depends on what sort of science… (Brian)
>
> There are all different types of scientists...They all study different types of things and so they all do different things. (Victoria)
>
> They study different things... (Yamina)
>
> It also depends what section they do in science… (Raashid)

This result was significant in light of the phrasing of most of the *VNOS-rs* questionnaire items as generic questions, that is, the students were asked to describe their views about ―science" and ―scientists", without specifying any particular field of science. This issue is discussed further in the Chapter Five (page 219).

The role/purpose of science

When asked to describe the reason/s that scientists do the work they do, a number of students mentioned a need to gain knowledge and understanding of the world in which we live (Gideon, Reza, Samuel, Victoria, Yamina), and to answer people‘s questions about living things (Dyllan, Yamina). Students also described scientists as enjoying their work (Aaeesha, Aamir, Dan), and as being curious about things as well as studying what they are interested in (Aamir, Maya, Raashid, Shanon). Some students said the role/purpose of science is to develop and improve the world (Brian, Shafia, Shanon), and to improve our lives (e.g., make our lives safer and easier) (Aaeesha, Gideon, Shafia). One student believed that the role of science included testing for aliens (Dyllan). These views are illustrated in the extracts below:

> [Scientists do their work] to help everyone understand the world better. (Victoria)
>
> To find answers...to the questions about the creature...[They want to know] what the creature probably looked like, how they lived, what they ate…[We want/need to know that] in case something like that comes up in the future. (Yamina)
>
> They do science because they like electricity and working with fluids. It‘s what they enjoy doing. (Dan)
>
> They like to invent things and they like to explore. (Aamir)
>
> [Scientists do their work] because they are interested in science...They are inquisitive to know more about the things they are studying. (Maya)
>
> To help develop the world...Their facts help us develop the world. Sometimes their facts help us make the world better…Well, they helped us to make diff- technology. ‗Cos our daily technology things we can‘t live without a cellphone, we always need a cellphone to call someone [to make] an important [call]…They make things to make life easier. Technology is things that make life easier…And they try to make different things that help us in our daily lives. Like when you first used to wash the dishes by hand, now you‘ve got a dishwasher…and you just put it in and it cleans it, for you, but my mommy still lets me wash the dishes by my hands, she says you have to learn to do it…Anyway, it‘s to make our life easier. A washing machine, we used to wash our clothes on our hands, so now we do our washing with a washing machine. (Shafia)
>
> People sometimes think they found an alien in their house then scientists do tests on it to tell that person if it is an alien or not. (Dyllan)

Evidently, it was not uncommon for the students to include references to the natural world in describing why scientists do the work they do. That is, their descriptions of the locations of scientists‘ work included references to elements of the natural world (e.g., plants and animals, the weather, space). These NOS views signalled possible links with the students‘ worldviews, which are included in the analysis of coherence presented in Part 3 (Coherence) of this chapter (page 178).

Further to these general results concerning the students‘ views of the role/purpose of science and the kinds of work that scientists do, this study was designed to enable the analysis of the students‘ views of five specific aspects of NOS. These results are presented next.

Range of NOS views (themes)

The study was designed to elicit the students‘ views, and to analyse their understanding about five aspects of NOS, namely, that scientific knowledge (1) is tentative (i.e., subject to change), (2) is based on empirical evidence and involves the use of observation and inference, (3) is theory-laden and subjective, (4) is socially- and culturally-embedded, and (5) involves the use of imagination and creativity. As previously explained (Chapter 3, page 72), items in the *VNOS-rs* questionnaire probed the students' views concerning these five NOS aspects. An analytic framework was developed in order to determine which aspect/s of NOS each statement related to, and to determine the level of understanding revealed by each statement (i.e., informed, developing or naïve) (Chapter 3, page 78). Amongst the fourteen cases studied, a range of NOS views was recorded in response to the *VNOS-rs* questionnaires and additional discussions, as well as the follow-up interviews. Within this range of NOS views, a number of themes were identified. These themes were employed in the analysis of the students' various statements about NOS. Identification of these various themes amongst the students' NOS responses constituted a detailed answer to the research sub-question for NOS (i.e., concerning the views the students held regarding each of the target NOS aspects). A synopsis of the range of NOS responses elicited from the students is presented below. These results have been organised according to each of the five NOS aspects, and in relation to various levels of understanding (i.e., informed, developing, and naïve). For the first NOS aspect (i.e., tentative, subject to change) the synopsis of the range of students' views is accompanied by the actual theme labels and definitions employed during the analysis of these NOS responses. The various response themes are illustrated by means of original extracts from the students' statements (i.e., written responses on the *VNOS-rs* questionnaire, and follow-up interviews). However, for the sake of brevity, the themes and illustrative extracts relating to the remaining four NOS aspects are located in Appendix 4.1 (page 347).

Tentative, subject to change

The students' informed understanding of the tentative aspect of NOS comprised views that existing science facts can change over time. This, according to the students' views, is for two reasons: first, scientists can change their minds about existing facts because they have found more evidence and change their minds; or, second, because new evidence shows their previous ideas were wrong. It is possible that scientists can make mistakes and then change what they say. In science, the facts can also change as technology becomes more accurate (Table 4.1).

Developing views of the tentative aspect of NOS were that scientists can sometimes add new facts to their existing knowledge (i.e., add-on view). Such additional findings might be as a result of changes that happen in the world, because scientists do not know everything, or if scientists have made an error in their work or drew an incorrect conclusion previously. Scientific knowledge can also change when scientists achieve what was previously considered

Table 4.1: Range of **informed** views regarding the **tentative** aspect of NOS

Theme label	Theme definition	Illustrative responses from the students
FACTS CHANGE	Facts are eventually changed over time.	―I‘ve got a example for scientists changing their facts…Like, who told my dad that there was just blackness in space? Probably his last science teacher. And now a new science teacher is saying there‘s stars and stuff like that. Or they‘re saying that, **back then they were probably saying** that it‘s one sun and nine planets **and now they're telling us** that there‘s plenty. That‘s an example of facts changing.” (Dyllan) ―. **I think that even if they tell us stuff now, I think there's a very good chance of it being different in the future**…I think that everything has to change eventually...so I think even if they tell us stuff now, I think it‘s possible that could change in the future [including the facts that scientists have confirmed. [And that‘s okay, it‘s all part of what science is about.]” (Gideon)
FIND MORE FACTS & CHANGE	Scientists could find more facts and then they change their minds.	―Being able to live in space permanently. They say it is not possible now but in the future I think it might be... e.g., Evolution: it is possible to evolve more still. Like, thousands of years ago from cavemen to how we are now…They might change their minds (i.e., about existing facts). **Just because they've proved something now, in 20 or 30 years' time they can go back to it and they might have more information**. It‘s happened before.” (Gideon) [Scientists might change their minds about existing science facts] i**f they find new information. Then the old facts won't be relevant any more**. And that‘s okay. (Victoria)
MORE FACTS & WRONG	Scientists might find more facts, and find that they were wrong before, and replace their previous ideas.	―They can‘t always be right…**They might find more information** after a while, then they put it together, **and they find they made a mistake somewhere**.” (Shafia) ―…They thought it was impossible to go to the moon. Now it‘s a fact—it‘s happened…e.g., Nine planets: **now it's been proved wrong**. Now there are ten.” (Gideon)[7]
IMPROVED TECHNOLOGY	New technology enables scientists to become more accurate, and then they‘ll change the facts.	―Scientists say that there is an Earth like ours somewhere else. They say that the fastest rocket will take 300 000 years to get there. Maybe they‘re wrong…**With new technology**. Maybe our fastest rocket will be faster so it will take only 200 000 years to get to the other Earth. Or maybe that Earth is closer than what they say it is.” (Dyllan) ―**Technology becomes more accurate as the years go by so the facts that exists now will be more accurate in a couple more years so maybe they will change the facts**… i.e., They get more accurate. If the technology gets better they‘ll find out more about something. Maybe existing facts will also change.” (Aaeesha)

[7] Xena was identified as a tenth planet, beyond Pluto.

Table 4.2: Range of **developing** views regarding the **tentative** aspect of NOS

Theme label	Theme definition	Illustrative responses from the students
ADD NEW EVIDENCE	Scientists could find new evidence and add it to what they already know (not necessarily changing the previous facts).	―**If they find something new**, e.g., old buildings from what they‗ve dug up." (Aamir)
MISTAKES	Scientists could make a mistake, miss something, or come to a wrong conclusion while they are working.	―They might use a different amount of chemicals to what they are supposed to use so **they get wrong answers**. Mostly they don‗t get it wrong, but sometimes they do. Not most of the times [but] sometimes they might add a different amount of something and then the exact amount, so it won‗t be stable." (Aamir)[8] ―Say the Voyager 1 passed Pluto and now it‗s shut down, it‗s not getting any sunlight and now it‗s travelling for a long time and there‗s a planet that looks similar to Pluto or maybe has the same structure as Pluto and now they get sunlight again and they say, ‗Ah, it it‗s just past Pluto, and it receives light from somewhere else.‗ **But it's not** Pluto. It‗s, like, a different planet. Something like that." (Dyllan)
CHANGING WORLD	The world is changing and you don‗t know what can happen.	―You can‗t give an example of what is going to happen in the future because **you don't know what is going to happen in the future**. Only God knows." (Raashid)
CREATE NEW INVENTIONS	Science also involves inventions and creating new things, so there are possibilities for new things in the future.	―It‗s not based on facts only. It‗s sometimes based on…like, people see, **they plan to try create something new**, like a vacuum cleaner. People didn‗t believe there could be something automatic to make it…And for, like I said about the plane. People thought it‗s impossible to have a flying plane. It‗s a myth that someone can…they think it‗s impossible. Like, it‗s a fact that it‗s impossible but then someone really makes it. Like, then, when they had carriages, they didn‗t believe that they would get a motorised car. They wouldn‗t even think about something like that." (Raashid) **Scientists can create new machines and discover more with modern day equipment**...They might add on things to what they made already (e.g., inventions). (Dan)

[8] The phrase ―...won‗t be stable..." refers to the outcome being variable (i.e., changing).

Table 4.3: Range of **naive** views regarding the **tentative** aspect of NOS

Theme label	Theme definition	Illustrative responses from the students
NO CHANGE	Facts don‘t change.	“Things they tell us about (e.g., cheetah) won‘t change…e.g., tree—they might want to experiment on it and make it grow more before they cut it down. What they find out about the tree **will not change**.” (Yamina) “No, they will tell us about the facts and future so that we can get knowledge about the future...Then if we become scientists we can also know. We know we don‘t need to search for that, we can go onto a different thing. Those facts **don’t change** so we can pass them onto the next people.” (Reza)
WON‘T TELL US	If the facts did change, scientists wouldn‘t tell us about it.	“The facts don‘t change. And if they did, **they wouldn’t tell us about it**.” (Brian)
CONFUSION & DOUBT	If scientists change the facts, then people won‘t know what to think, or they won‘t believe scientists.	“They have to have everything right about that things they discovered. e.g., before it‘s in the newspaper, probably the whole world already knew, **the people don’t know what to think**.” (Aamir)[9] “If they tell the public about the facts and scientists change the facts **then people won’t believe scientists**.” (Brian)
NO MISTAKES	Scientists don‘t make mistakes; they triple-check everything before they tell us.	“They are clever and **most of the time they never get anything wrong**.” (Aamir) “…I‘m sure that a lot of scientists make mistakes all the time but then they don‘t go, they‘re not…scientists, they...**triple check**, they go over and over again just to make sure it‘s perfect, so if they do make mistakes, then hopefully they‘re gone over again and then **they’ll correct it before it gets out to us**…” (Shanon)

[9] Re-phrased: They have to have everything right about the things they have discovered, before it is published in the newspaper and the whole world knows—because if they change it after that, then people won‘t know what to think.

impossible (i.e., technological advances and inventions). Such NOS views were not considered to be informed as they focused more on the addition of new knowledge than on the possibility of existing knowledge changing (Table 4.2).

Naïve views of the tentative aspect of NOS were that existing facts do not change, and even if the facts did change, scientists would not make it publically known. Some of the students held the view that if science facts change, then people would not know what to think and they would not believe scientists. Furthermore, there was a view that scientists check everything thoroughly before they tell us, and that scientists do not make mistakes (Table 4.3).

Empirical evidence

Informed views of the empirically-based aspect of NOS included understanding that science is based on factual knowledge as well as inferences derived from facts. Students stated that scientists study and observe things in Nature by going to a location and searching for evidence, which is then analysed. Scientists conduct research and they do investigations and experiments. Science also involves discoveries and inventions. Facts include archaeological evidence such as bones, teeth and fossil records, and soil samples. Scientists also use technology to find out things, such as machines and computers, satellites, and measurement instruments. Tests are conducted in a science laboratory so that facts can be proven, and scientists check their work in order to avoid publicizing erroneous information (Appendix 4.1, Table A4.1-1, page 347).

The students' understanding of the empirically-based aspect of NOS were regarded as developing when their views included statements that scientific knowledge is based on evidence and other things. In some cases, although students made reference to scientists conducting investigations and searching, they expressed a degree of uncertainty about the way in which scientists actually collect their evidence. In other cases, the students held doubts regarding what scientists tell us (Appendix 4.1, Table A4.1-2, page 354).

Naive views of the empirically-based aspect of NOS were that scientific knowledge is not based on facts. Some students did not know how scientists obtain their knowledge. Further naïve views included statements that scientists not only tell us information that is incorrect, but they are also dishonest and corrupt people, who are simply seeking personal fame (Appendix 4.1, Table A4.1-3, page 355).

It is important to note that in analyzing the students' responses concerning the empirically-based aspect of NOS, the focus was on whether or not the student recognized the role of empirical evidence in the construction of scientific knowledge (e.g., a description of the use of computer equipment, scanning devices and satellites in science)—even if the students' descriptions of how these data are used were not completely accurate (e.g., how exactly certain equipment and data collection methods are employed by scientists). For example, Aamir described the use of computers and satellites in science, although he seemed to hold a limited understanding of how exactly these technologies are employed in science:

> [Scientists] can use a computer to look back in time...I don't know [how they do that because] I don't work with computers. They might have a different programme for the computer where they can run it through to the satellite. So the satellite…can tell them everything that happened.

Shafia's explanation of how scientists make weather predictions was inaccurate, however she did recognise the empirically-based nature of science:

> They use aeroplanes and machines and the wind...Before machines they predicted the weather with a thing made of wood. It turns something on top and an arrow goes to cold weather or hot, so they see if it will snow, etc.

In describing how scientists know what dinosaurs looked like, Aaeesha and Yamina mentioned scientists studying dinosaur bones and then scanning the skeleton into a computer to generate a completed image. Although the process of scanning was unclear, these two students recognised the role of evidence in science, and therefore their statements were considered to be informed.

> …They've first got the bones and then they put it together and then they scan it, like, on the computer... (Aaeesha).

> They found and studied the bones and put them together and to find out what dinosaur it was and ate…To find out about skin colour they scan it into a machine and it tells them (Yamina).

Theory-laden, subjective

Informed views of the theory-laden and subjective aspect of NOS included understanding that scientific knowledge sometimes involves what scientists think, including their beliefs and opinions, and things that scientists visualise in their minds. Sometimes scientists lack information, or they were not there at the time to observe what they are studying, and therefore need to develop theories to explain things. They take guesses and make estimations, based on the evidence they have obtained. Therefore, scientists are sometimes uncertain of what they tell us, and we are sometimes unsure of what they say. However, scientists test their theories in attempting to prove them right or wrong, and what they tell us must be plausible (Appendix 4.1, Table A4.1-4, page 357).

Developing views of the theory-laden aspect of NOS were that science involves both facts and opinions, but that opinions have less status than facts. Scientific knowledge is almost correct, although there are some things that scientists aren't 100% certain of—but these things become facts when scientists are sure about them. Furthermore, science involves more than facts—it includes inventions as well (Appendix 4.1, Table A4.1-5, page 359).

The students' naive understanding of the theory-laden aspect of NOS included views that scientific knowledge involves only facts, evidence and the truth, and that these are obtained with the use of technology. Science does not involve scientists' own thoughts or guesses. Some students recognized that scientists do not know everything, but they said that scientists' uncertainties only remain until they have collected enough facts. Before publicizing their knowledge, scientists first need to check their facts, confirm them to be correct and be able to prove them so. This said, however, some students stated they did not believe scientists as perhaps scientists do not tell us the truth (Appendix 4.1, Table A4.1-6, page 360).

Socially- and culturally-embedded

Informed views of the socially- and culturally-embedded aspect of NOS were that individual scientists have different ways of thinking and of seeing things, they hold different opinions and believe different things, and they research different questions. Scientists work in different ways, and different answers are therefore possible in science. Disagreements are resolved by determining a majority position and collating all of the available evidence (Appendix 4.1, Table A4.1-7, page 364).

Whereas informed views of the socially- and culturally-embedded aspect of NOS recognised science as a human endeavour, developing views of this NOS aspect included explanations that differences between scientists arise from methodological and/or evidence-related issues. The students' understanding of the socially- and culturally-embedded aspect of NOS was considered to be developing when they included views that scientists might indeed have different ideas, but this is because they have different information *and* different opinions. In addition to finding different evidence, scientists' disagreements could arise from them making mistakes or because they have used new or different technology to obtain their results. Disagreements are dissolved by searching for more evidence and perhaps finding that there is only one correct answer. However, scientists do not collaborate in their attempts to resolve disagreements, as they mistrust each other and they compete for individual fame (Appendix 4.1, Table A4.1-8, page 366).

The students' understanding regarding the socially- and culturally-embedded aspect of NOS was naïve when they involved the view that there should not be disagreements amongst scientists. There is a single correct answer, and eventually scientists will find that their different answers have the same meaning. If scientists have the same facts, then they will not disagree.

If they do disagree, then they need to search for more evidence (Appendix 4.1, Table A4.1-9, page 368).

Imagination and creativity

Informed views of the role of imagination and creativity in the development of scientific knowledge, included the understanding that scientists use their imaginations and creativity when there is evidence missing. In such instances, scientists begin with whatever facts they have, and then work toward developing explanations from these data. Scientists also use their imagination when they try different options to determine which one works best. They are creative when they invent new devices, and when they assign names to new animal species that are discovered (Appendix 4.1, Table A4.1-10, page 369).

None of the students articulated developing statements regarding the role of imagination and creativity in science. However, some students described a naïve understanding. These included the view that scientists don't use their imaginations or creativity because science is concerned with the truth. Scientists need to prove things when they are conducting an investigation and therefore cannot add in extra ideas that arise simply from their own thoughts. That said, students described how scientists use their imaginations when they try to remember things they have learnt previously, and they use their creativity when they present their work to other people (Appendix 4.1, Table A4.1-11, page 371).

Limited understanding and alternative meanings

During the analysis of the students' NOS responses, it was found that some individuals held a limited understanding and attached somewhat alternative meanings to terms they used. That is, statements relating to the empirically-based aspect of NOS revealed limited and inaccurate descriptions of archaeologists and the differentiation between science and history as fields of study. Some of the students' statements relating to the theory-laden aspect of science, revealed a limited understanding of the terms *fact*, *truth*, *myth*, *theory*, *opinion*, *imagination* and *guess*. Details of each of these will now be described in turn.

Archaeologists, palaeontologists, scientists and historians

Students' NOS statements typically included references to scientists studying evidence such as dinosaur bones and fossils. These responses were regarded as evidence of an informed understanding of the empirically-based aspect of NOS. However, such scientists were incorrectly identified as archaeologists, without any mention of palaeontologists. Indeed, students seemed unaware of the distinction between archaeology and palaeontology:[10]

> Archaeologists look for remains of dead dinosaurs under the surface. (Brian)
>
> [Re: Dinosaurs] e.g. Archaeologist finds bones, builds a skeleton and then tells us things like it was a meat-eater. (Victoria)
>
> Archeologists found bones, fossils, fossils of the dinosaurs, but obviously the skin has been eaten up by—and then, all they find is the bone, and they brush it and that, and all they see is the bone… (Dyllan)

In some cases, however, students' references to archaeologists were not incorrect. Archaeologists were identified as one of many different types of scientists, and their work was described as digging for physical remains, and discovering history:

> There are all different types of scientists, like archaeologists (they dig), biologists (look at the environment), geographers (look at the world and cities), and meteorologists (they study more of the weather). They all study different types of things and so they all do different things. (Victoria)
>
> [Re: What kinds of work do scientists do?] It depends on what sort of science…They discover history (i.e., archaeologists) or look deep into space (i.e., plants), try new inventions (i.e., robots), try new experiments (i.e., medicine), and find cures for illnesses. (Brian)

Nonetheless, it seems that some students held limited views of the work done by people named scientists as opposed to those we call archaeologists. Specifically, one student mentioned that archaeologists and scientists do different work (i.e., archaeologists study fossils and animals, and scientists experiment chemicals in a laboratory), but they are sometimes related in that scientists approach archaeologists for help:

> I think [archaeologists and scientists] are connected with some way…When the scientists do research on the thing, and then they will go to archaeologists to help them…A scientist will work in a laboratory with different things, like, concoctions together, and the archaeologist will just study fossils and creatures. (Yamina)

Furthermore, some students did not differentiate clearly between science and *history* as distinct fields of study. More specifically, no distinction was made between history and archaeology. For example, Maya stated that scientists study historical artifacts such as pieces of old pottery or gold. This is the type of work that would be done by archaeologists:

> When they can't really find a picture of old things they need to kind of make a picture in their brain what it would look like…[They use their imagination based on facts that have been found]…e.g., A piece of clay: it must be pottery; A piece of gold: must have been jewellery. They find out who made it and why. Then they can search further. For example, go to the people who made it. (Maya)

[10] Archaeology, a subfield of anthropology, is "the study of human history and prehistory through the excavation of sites and the analysis of physical remains" (Kavanagh, 2007:55). Palaentology is "the branch of science concerned with fossil animals and plants" (Kavanagh, 2007:837). Therefore, whereas archaeologists study people and their cultures by analyzing artefacts that have been made and modified by humans, palaeontologists study extinct animals and plants by analyzing fossils and other evidence of former living plants and animals.

Reza and Raashid also seemed to be describing the work of archaeologists in their statements concerning scientists visiting different locations to investigate past cultures and find historical artefacts:

> ...scientists study other people's cultures—from long ago... They investigate and search about old things what happened in the old days…By looking in the past what has happened (e.g. Khoikhoi and San). Go to different places and search what did they do (e.g., Khoikhoi/San) (Reza)
>
> [Scientists do their work] I think because they are interested in…discovering old…things in the world...They find stuff in the world that link up with history… (Raashid)

However, in some cases, it was unclear whether the students were referring to archaeology or history in describing the work that scientists do:

> [T]hey discover history… (Brian)
>
> Scientists study and research things, for example, plants, animals, people…When I talk about research, is when you go out and you look for something. Research means looking for something to me…Like I might be researching a country… Researching is finding out things about that thing… You would either go to the country, also the people who live there, ask them about their old cultures, go to the museums, look in their libraries, that's how you'd find it. (Shafia)

In summary, there seems to have been some confusion amongst the students regarding the distinction between science and history as fields of study, including the difference between history and archaeology, and between archaeology and palaeontology, and concerning the relationships between different types of scientists (e.g., physicists/chemists and archaeologists).

Fact, myth, theory, opinion, truth, imagination and guesses

The students' responses relating to the theory-laden aspect of science revealed a limited understanding of some of the terms they used, such as, *fact*, *myth*, *theory*, and *opinion*.

Facts vs. myths

Some students described scientific facts as being evidence-based and representing something that has been discovered:

> Fact = different things that were discovered. (Aamir)

Moreover, facts were described as that which scientists are certain of and tell people about, as opposed to things that scientists are unsure of and which have therefore not yet been publicised:

> Because some stuff today they are accurate and there are facts and lots of other stuff...Other stuff refers to] stuff they're not sure about yet and they find out more about it at the moment. Then they'll become facts when they are sure about it...[Other stuff is also]…things they know, but they're not sure about it, so they're not telling other people. They just want to find out more about it first… Some of it can become facts. Um…Actually, they can become facts if they're sure about it… (Aaeesha)

In contrast, myths are stories about what might possibly be achieved one day, and these accounts could change in the future. Myths are not part of science. Facts describe what has happened, and this does not change. Myths can become facts when they are confirmed:

> Once you have done experiments and have confirmed what you thought were myths become facts...Examples of myths: They thought it was impossible to go to the moon. Now it‛s a fact—it‛s happened...e.g. Nine planets: now it‛s been proved wrong. Now there are ten. (Gideon)

> Myths aren‛t part of science—only when they‛ve been confirmed. (Gideon)

> For a very long time people have been talking about going to the moon, and it happened about twenty years ago, it happened about three years ago. So, I mean, the question is, was it or was it not a…myth before it happened? [And they say it‛s not possible now to live in space permanently but in the future it might be…] Is it a fact, or is it just a story…? [And with evolution, it is possible to evolve more still, but it‛s in the future and we don‛t know what‛s going to happen in the future…[That is not part of science] because I think that even if they tell us stuff now, I think there‛s a very good chance of it being different in the future… (Gideon)

Facts vs. theories

Theories are when different scientists believe different facts:

> Some of the scientists believe different facts and that then makes them theories. (Victoria).

Theories are also things that are in the process of being proven or disproved:

> It can be based on a belief, a term, an object, a human—almost anything….A term is a theory, an object is, for example, a tree, a human is us!…[A term/theory is something that you‛re trying to prove yes, it‛s right or no, it‛s wrong]. (Shanon)

Facts vs. opinions

Facts deal with the past, and opinions are concerned with the future:

> Opinions are part of science because they are part of an invention which could be successful (e.g., a car that‛s now on the road) or it could fail. (Dan)

Also, facts are things you know to be true, whereas opinions are statements that could possibly be true:

> A fact is, for example, once dinosaurs walked on the Earth,, that‛s telling what happened in the past. An opinion is, for example, the biggest dinosaur to walk on Earth was Tyrannosaurus Rex...Because you think that it‛s the largest, and you don‛t know that it‛s the largest. [It would be something you know] if you looked it up on the Internet and then it said ―facts about dinosaurs" and then it said the—. (Dan)

In addition to these limited understandings of the terms *fact*, *myth*, *theory*, and *opinion*, there were students who attached somewhat unconventional meanings to the terms *fact* and *truth*, and to the terms *imaginations* and *guesses.*

Facts vs. truth

Yamina‛s references to *fact* and *truth* revealed that she assigned alternative meanings to these terms. According to her, facts originate from the thoughts of people, and include inferences based on evidence studied and statements about what might have happened in the past. In contrast, truth is what is real and true. Facts can become truth when they have been confirmed. As such, *facts* seemed to refer to theory and inference, and *truth* seemed to refer to facts and evidence:

> Some scientists find the truth about Nature...Facts are things they‘ve thought of so they come from people. Truth is what it is really. Science is more based on truth but there are facts involved...They come to their facts because they see it in their work. Then as they‘re studying that thing they see something else—they add that piece of knowledge to the rest of the truth. Then it becomes part of the truth. (Yamina)

> They picture what the creature or thing looked like...If they don‘t know what the creature looked like they‘ll listen to the name and try to picture what it looked like. They use different animals that have a similar sounding name. Then they‘ll use a part of that animal to the animal that they are studying. They find the facts about it and that is then the truth. (Yamina)

> The truth is the truth. And facts are what could have happened while the creature was alive…[Facts] can become the truth as they research deeper into the creature. (Yamina)

Guesses vs. imagination

Maya assigned alternative meanings when referring to scientists *guessing* and using their *imaginations*. According to her, when scientists use their imaginations they are making inferences based on the evidence they have, but their guesses are not empirically-based:

> [Guessing is] kind of similar [to when they use their imaginations to work out stuff]. They use their imaginations…because they might have two options and they go, okay, which one could it be? [So it is working it out from the fact. But a guess is not really as based on the facts. So you trust the imagination and that would be part of science, but the guessing wouldn‘t…] because then it‘s not actually going out further, they‘re just guessing. [When they guess] [they‘re basing it on] whatever they are trying to find, like they could just say dinosaurs were pink, but even though they might not have been pink. (Maya)

In a number of cases, the students‘ limited and alternative understanding of the terms *fact*, *truth*, *myth*, *theory*, *opinion*, *imaginations* and *guesses* emerged during their initial written responses to the *VNOS-rs* questionnaire. These responses were probed further during the immediate review of their written answers as well as later during the follow-up interviews, in order to clarify the meanings of these statements for a more accurate analysis of their NOS views.

In summary, the students articulated a range of views pertaining to various levels of understanding about each of the five NOS aspects. Furthermore, their NOS responses included some limited and alternative understanding concerning different fields of science and the kinds of evidence studied in each field (e.g., archaeology, palaeontology, science and history), and also concerning the meanings of the certain terms pertaining to the role of evidence and theory in science (e.g., *fact*, *truth*, *myth*, *theory*, *opinion*, *imaginations* and *guessing*). In addition to these results, the students‘ NOS views were found to be rich. Data concerning the richness of the students‘ views are presented next.

NOS views are rich

Careful analysis of each NOS statement articulated by individuals revealed that the students sometimes articulated views that were related to more than one aspect of NOS (e.g., theory-laden and imaginative/creative aspects). Furthermore, students‘ NOS views pertaining to a particular NOS aspect sometimes comprised various levels of understanding (e.g., a combination of naïve and informed statements).

The students' statements related to multiple NOS aspects

In all fourteen cases, students articulated NOS statements that were related to more than one NOS aspect, as illustrated by three examples provided here.

In the first example, the student‘s two statements about dinosaurs reveal informed views of both the empirically-based and theory-laden aspects of NOS:

> …If you‘ve got a full skeleton and…you can see that one of their fingers are missing and you‘re looked around that square kilometre or whatever and you can‘t find it there, then they might just estimate or make up that bone just to complete it.
>
> I‘d say 90% is based on facts and the other 10% or whatever is…estimating. (Samuel)

In the second example, the student‘s statement indicates informed views of both the theory-laden and socially- and culturally-embedded aspects of NOS:

> They have different theories. They experiment differently with the bones and it gives them different answers…They have different thoughts about it and do it in different ways. (Shanon)

In the third example, the following statement reveals informed views of both the theory-laden aspect of NOS and the role of imagination in the NOS:

> Science is about more than the facts. You need your own opinion and sometimes you must also use your imagination. (Shafia)

Students' NOS statements related to multiple levels of understanding

In eleven of the fourteen cases (i.e., Aaeesha, Aamir, Brian, Dan, Dyllan, Maya, Raashid, Reza, Shanon, Victoria, Yamina), students‘ NOS views included statements relating to more than one level of understanding of a particular aspect of NOS. Five examples are provided here, one for each of the five NOS aspects.

First, Aamir‘s statements relating to the tentative aspect of NOS revealed naïve views and developing views (Table 4.4). His naïve understanding concerned the view that scientists do not change what they have said, because they are clever and do not make mistakes, and also that scientists cannot change facts that have already been published because the public would become confused. However, Aamir‘s view that scientists could find something new is an add-on view[11] and therefore corresponds to a level of NOS understanding that is developing (Appendix 3.12, Table A3.12-1, page 295).

Table 4.4: Selected statements articulated by Aamir relating to the tentative aspect of NOS

Developing view	**Naïve view**
[Scientists might change what they said] If they find something new e.g. old buildings from what they‘ve dug up.	They are clever and most of the time they never get anything wrong. They have to have everything right about that things they discovered. For example, before it‘s in the newspaper, probably the whole world already knew, the people don‘t know what to think.

Second, Yamina‘s understanding of the role of empirical evidence in science included both informed and naïve NOS views (Table 4.5). She described informed views that scientists‘ knowledge of dinosaurs is based on the study of bones and fossils, and that scientists study the weather with the use of measurement instruments. However, she also said that scientists cannot be trusted as they might misinform people in order to protect their research from theft. This apparent disregard for the rigour of the scientific enterprise was regarded as a naïve NOS view (Appendix 3.12, Table A3.12-2, page 296).

Third, Aaeesha‘s statements relating to the theory-laden aspect of NOS included views that were both informed and naive (Table 4.6). She stated that scientists‘ pictures depicting dinosaurs are what they think dinosaurs looked like, which indicates an informed NOS view that scientific knowledge involves some speculation. However, Aaeesha also held the view that scientists only tell other people things that they are sure about and which have become facts, and this is a naïve understanding (Appendix 3.12, Table A3.12-3, page 297).

Fourth, Victoria articulated informed, developing and naïve views concerning the socially- and culturally-embedded aspect of NOS (Table 4.7). Her informed view included an understanding that science is a human endeavour, in that different scientists believe different facts, and scientists apply their own insights in interpreting the facts they find. Victoria went on to say

[11] ‗Add-on views‘ acknowledge that scientists are still discovering new data, and therefore it is possible for new knowledge to be added to the existing body of scientific knowledge. However, in such views, there is no reference to *existing* facts undergoing change (Appendix 3.12, Table A3.12-1, page 289).

that disagreements are as a result of scientists collecting different facts as well as their different opinions, which is a developing view. Victoria‘s statement that the same facts should not elicit different opinions was regarded as a naïve NOS understanding (Appendix 3.12, Table A3.12-4, page 298).

Table 4.5: Selected statements articulated by Yamina regarding the empirically-based aspect of NOS

Informed view	**Naïve view**
They found and studied the bones and put them together and to find out what dinosaur it was and ate. [When they study fossils] maybe they will break it open and look at it and feel the different textures…[in the lab]. They use a machine to discover what the weather will be…It has the temperature in a box and then they‘ll open the box to see what the temperature will be.	They might tell us something is not going to happen to kill us…Like a meteor coming to Earth—they won‘t tell us because they want to kill us! Because they think we are robbers trying to steal their research. I really do think so. [We can‘t always trust what scientists tell us because] they might think that you‘re a robber, and then they will tell you there‘s not a meteor coming, but then it really is coming, just to kill you and will say it‘s not coming in your area and its coming in some other area and the people are already evacuated and it‘s really coming to your area…[but the scientist won‘t also get killed] because he‘ll be gone already...[Or] you might have a baby dinosaur in his lab, and he‘ll say, ―No, it‘s just an experiment of some other creature,” then you decide, ―okay, I‘m going to steal this creature and I‘m gonna sell it”, but then it‘s really a dinosaur. And when it grows up it bites your head off and you die!...[But we can believe what scientists say] about the plants and animals fossils.

Table 4.6: Selected statements articulated by Aaeesha relating to the theory-laden aspect of NOS

Informed view	**Naïve view**
They don‘t know for sure but what they found so for the picture indicated is what they think dinosaurs look like.	Because some stuff today they are accurate and there are facts and lots of other stuff (4.d.)…[Other stuff refers to]…things they know, but they‘re not sure about it, so they‘re not telling other people. They just want to find out more about it first… Some of it can become facts. Um…Actually, they can become facts if they‘re sure about it... Well, they have to find out more and more until…[they are sure about it…so that it can be facts.

Table 4.7: Selected statements articulated by Victoria relating to the socially- and culturally-embedded aspect of NOS

Informed view	**Developing view**	**Naïve view**
Some of the scientists believe different facts and that then makes them theories. You take your facts and you‘d add your own opinion to it, to make sense of it, and then you make a story out of it that you tell people.	So the fact that they disagree shows you that there must be different facts and that there must be different opinions involved.	If they all have the same facts they wouldn‘t really disagree on things. They would agree on things because the facts would be very similar.

Fifth, the following statements from Shanon reveal that her understanding of the role of imagination and creativity in science is partly naïve and partly informed. She holds the naïve view that when trying to prove something, scientists‘ imaginations are not involved, because then the facts would be ―rubbish”. However, she goes on to say that scientists use their imagination when they are creating and inventing things, and this could be regarded as an informed NOS statement (Appendix 3.12, Table A3.12-5, page 299):

> [Re: Do scientists use their imagination and creativity when they do their work?] Well, I hope not, because then every ―scientific” fact will be rubbish. Scientists need to find the truth, not the imagination in their heads. But sometimes, when they are creating things, they use imagination…If they‘re inventing something then it‘s okay that they use their imaginations. It‘s not okay if they‘re trying to prove something.

As previously noted, in determining the overall level of understanding concerning a particular NOS aspect, all of the student‘s relevant NOS responses were considered together. For example, Raashid‘s responses relating to the role of imagination and creativity in science included both informed and naive views (Table 4.8). Specifically, Raashid seemed to have an informed understanding of scientists‘ use of creativity in advancing technology designing and new things. However, the use of imagination was not recognised during scientists‘ investigations or in researching details about the past. Therefore, Raashid‘s overall level of understanding was regarded as developing.

Table 4.8: Raashid‘s responses relating to the imaginative and creative aspect of NOS

Informed view (Creativity)	**Naive view (Imagination)**
They create and test stuff. They improve technology in the modern world. It also depends what section they do in science… They discover stuff that hasn‘t been discovered yet, and they discover history and create new things. [They use their imaginations/creativity] when they are creating something (what the thing looks like, etc.)...For example, toasters (different styles), cars (different types and colours and looks)...[And] for example, experiments—make medicine. They try stuff to see if it will work. For example, cure of AIDS; e.g., structures. It‘s not based on facts only. It‘s sometimes based on…like, people see, they plan to try create something new, like a vacuum cleaner. People didn‘t believe there could be something automatic to make it…And for, like I said about the plane. People thought it‘s impossible to have a flying plane. It‘s a myth that someone can…they think it‘s impossible. Like, it‘s a fact that it‘s impossible but then someone really makes it. Like, then, when they had carriages, they didn‘t believe that they would get a motorised car. They wouldn‘t even *think* about something like that. [Re: visions that scientists have]…If you had a vision of creating…let me try a vacuum cleaner again…The person, they didn‘t believe that they could happen, like the aeroplane. They were like, ―Oh, it‘s impossible, never mind.”…They try and try, but they never succeed, like the aeroplane. Say now the person he sees something that…a person can maybe make…in the future. Like, people now believe that it will be flying cars in the future…Like, say now, the guy tries, he doesn‘t make it, he tries, and eventually he ends up making a real vacuum cleaner that works.	[Re: Scientists don‘t use their imaginations/creativity] Not when they discover history. You can‘t just take guesses and use your imagination. You need proof. e.g. what people looked like. e.g., not when they do investigations.

The NOS results presented thus far have offered a global perspective of the findings for all cases. The next section focuses on the results for individual cases, in order to show the diversity of NOS views described by each of the cases studied.

NOS views are diverse (NOS profiles)

In studying the students' NOS views, a profile was developed for each case. Examples of students' NOS profiles are provided in Figure 4.2 and Figure 4.3, which demonstrate the uniqueness of individuals' NOS views (the NOS profiles of the remaining cases are provided in Appendix 4.2, page 372). Each NOS profile comprises two parts, namely, a summary of the student's levels of the understanding pertaining to each of the five target NOS aspects, and a synopsis of the contents of the student's NOS views. The NOS profiles were compiled as described below.

Summary of levels of understanding: As previously explained (Chapter 3, page 78) analysis of the students' NOS views proceeded by first identifying which statements related to each NOS aspect. The level of understanding indicated by each response was assessed by comparing the particular response with the contents of sample NOS views presented in the analytic framework for NOS (Chapter 3, page 78), and determining which level of understanding the statement represented. All the statements relating to a particular NOS aspect were then considered together in order to determine the student's overall level of understanding about that NOS aspect. The overall results for all five aspects are represented diagrammatically on the right-hand-side of each student's NOS profile.

Synopsis of contents of NOS views: The student's responses relating to each NOS aspect were considered together, and the salient views were distilled in order to compile a snapshot of the contents of the student's NOS views. This is presented on the left-hand-side of the NOS profile.

NOS profiles were compiled in order to provide an overview of each case and to facilitate comparison between cases were necessary. The NOS profiles for Aaeesha and Aamir are presented here, while the NOS profiles for the remaining cases are presented in Appendix 4.2 (page 372). Inspection of the students' NOS profiles reveals that no two students held identical views of NOS, and therefore each NOS profile was unique. As such, there was found to be great diversity amongst the NOS views of the fourteen cases studied—both in terms of the contents of each individuals' views, as well as in the various levels of understanding that individuals held about each of the five NOS aspects. Further analysis of the students' various levels of understanding revealed that, overall, their NOS views were somewhat informed, as presented next.

AAEESHA

- As technology becomes more accurate, scientists' facts will be more accurate, so maybe then they will change the facts
- Scientists do research and experiments with what they've got and things they've found
- There are things scientists aren't sure about—they find out more until they're sure, then it becomes facts
- Scientists think differently and they get different information so they might disagree
- Scientists use their imaginations/creativity in telling us what dinosaurs looked like and were named, and in designing/creating new devices (e.g., microwave oven)

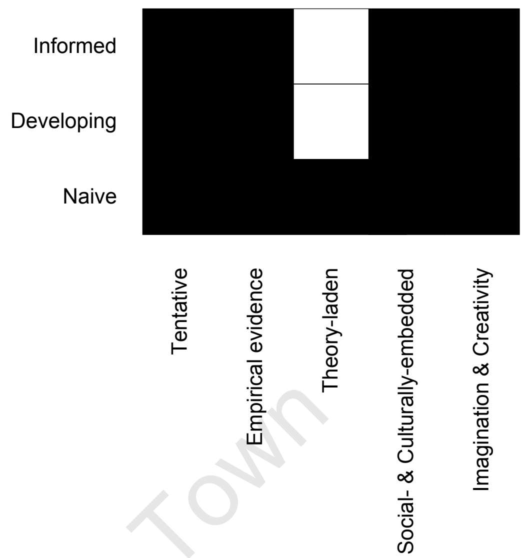


Figure 4.2: NOS profile for Aaeesha

AAMIR

- Scientists might find they have done something wrong in their experiments, but mostly they don't get anything wrong because they are clever—they have to have everything right before it's in the newspaper or people won't know what to think
- Science facts are things they've discovered, or from investigations using machines and chemicals
- Scientists use technology, and it is usually not wrong, so you can trust what they say
- If scientists disagree it's because one of them has different facts, but eventually they'll figure out it's actually the same
- Scientists like to invent things—their minds run wild when they are thinking about what they want to do, and when they are remembering things they've learnt before

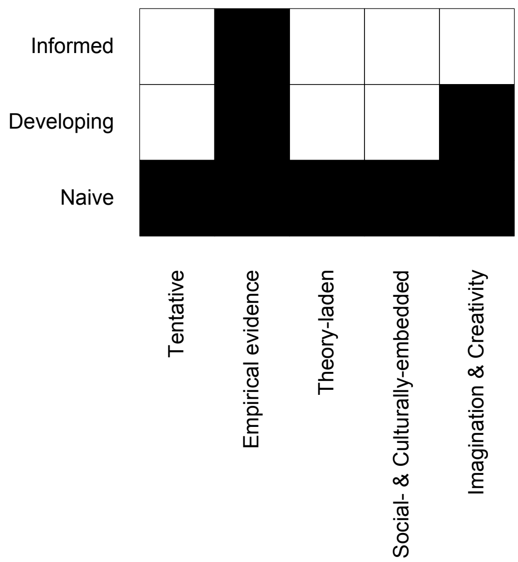


Figure 4.3: NOS profile for Aamir

NOS views are somewhat informed

The NOS results presented thus far have shown the range of views described by the fourteen students pertaining to various levels of understanding about each NOS aspect. Furthermore, the NOS views of individuals were found to be rich, in that a single NOS statement sometimes revealed views about multiple NOS aspects, and individuals sometimes described views regarding a particular NOS aspect that related to more than one level of understanding. A NOS profile was developed for each student, showing the diversity of views represented by the fourteen cases, both in terms of levels of understanding and with regard to the contents of the students' NOS views. These NOS profiles enabled a broad comparison between the various cases, which was necessary later in exploring relationships between students' NOS views (summarised in the form of a NOS profile) and their worldviews (summarised in the form of a worldview profile). Table 4.9 provides a summary of the overall levels of understanding held by the students concerning each of the five target NOS aspects.

Two main findings are evident from the above data. The first concerns the students' overall levels of NOS understanding, and the second concerns the various combinations of levels of understanding that constitute each student's overall NOS views. First, Table 4.9 shows that five students held NOS views that were largely informed, three students' NOS views were somewhat informed, four students held NOS views that were developing, and only two students held NOS views that were largely naive. Therefore, in more than half of the cases studied, the students described NOS views that were either somewhat or largely informed, but in only two cases (i.e., Victoria, Shafia) did students hold informed views of all five NOS aspects.

Second, Table 4.9 shows that individuals' levels of understanding were not the same for all five NOS aspects. For example, Brian held an informed understanding of one aspect, a developing understanding of two aspects and a naive understanding of two aspects, and Maya held an informed understanding of three aspects, a developing understanding of one aspect and a naive understanding of one aspect. These data suggest that the students' NOS understanding did not develop uniformly for all five aspects.

Indeed, analyses show that the students held the most informed views of the empirically-based aspect of NOS, followed by their views regarding the role of imagination and creativity in science, and then their views of the tentative and socially- and culturally-embedded aspects of NOS (Table 4.10). The students held the least informed views of the theory-laden aspect of NOS.

Table 4.9: Levels of understanding for each student, detailed per NOS aspect and loosely arranged in descending order overall for all cases

Case name	**LEVEL OF UNDERSTANDING PER NOS ASPECT**					**Overall level of understanding**
	Tentative	**Empirical Evidence**	**Theory-laden**	**Social/ cultural**	**Imagination & Creativity**	
Victoria	Informed	Informed	Informed	Informed	Informed	Largely informed
Shafia	Informed	Informed	Informed	Informed	Informed	
Aaeesha	Informed	Informed	Naive	Informed	Informed	
Samuel	Informed	Informed	Informed	Informed	Naive	
Gideon	Informed	Informed	Naive	Informed	Informed	
Maya	Informed	Informed	Naive	Developing	Informed	Somewhat informed
Dan	Developing	Developing	Developing	Informed	Informed	
Shanon	Developing	Developing	Informed	Informed	Developing	
Raashid	Developing	Informed	Developing	Developing	Developing	Developing
Yamina	Naive	Developing	Informed	Naive	Informed	
Brian	Naive	Informed	Developing	Developing	Naive	
Dyllan	Informed	Naive	Naive	Naive	Informed	
Aamir	Naive	Informed	Naive	Naive	Developing	Naive
Reza	Naive	Developing	Naive	Naive	Naive	

Table 4.10: Students' levels of understanding regarding each NOS aspect, for all fourteen cases

Levels of understanding per NOS aspect	Tentative		Empirical evidence		Theory-laden		Social/ Cultural		Imagination & Creativity	
	No. cases	%	No. cases	%	No. cases	%	No. cases	%	No. cases	%
Informed	7	50.0	9	64.3	5	35.7	7	50.0	8	57.1
Developing	3	21.4	4	28.6	4	28.6	3	21.4	3	21.4
Naive	4	28.6	1	7.1	5	35.7	4	28.6	3	21.4

This lack of uniformity within individuals' NOS views is related to the overall coherence of the students' NOS views, and this aspect is presented next.

Lack of internal coherence: System complexity & system incoherence

A large number of the students' NOS views (8 of the total 14 cases) contained instances of system incoherence (i.e., conflicts within their NOS views) and/or instances of system complexity (i.e., complexities or inconsistencies within their NOS views that were not strongly opposed enough to be termed system incoherence). Specifically, two students' NOS views revealed instances of system complexity (i.e., Samuel, Gideon), and a further six students' NOS views revealed instances of system incoherence (i.e., Shanon, Yamina, Raashid, Dan, Dyllan, Brian). The various instances of system complexity and system incoherence within the students' NOS views were related to the following issues:

1) Why scientists do their work
2) Where and how science is done
3) Disagreements vs. one answer
4) Scientists know vs. God knows
5) The role of empirical evidence in science vs. disbelief/doubt in scientists
6) The role of confirmed facts vs. Imagination/estimation in science

These instances of system complexity and system incoherence within the students' NOS views draw attention to the inherent complexity of NOS. This issue is discussed in detail in the next chapter (page 226).

Below, details are provided of the various instances of system complexity and system incoherence that were identified within the students' views of NOS, by presenting each issue in turn.

Why scientists do their work

Shanon stated that scientists aim to develop things in order to improve the world, but she said that sometimes the impact of their work is negative rather than positive (System incoherence).

Improving the world:

> A scientist‘s goal is to develop things…They want to improve the world and they have a curiosity to see what will happen.

Making things worse:

> They discover how things work and develop them to make the world more advanced to help us. But sometimes they just make it worse, like global warming.

Where and how science is done

Dan‘s view that scientists do their work in a laboratory, was incoherent with his descriptions of scientists visiting a forest, finding dinosaur bones and observing weather phenomena (System incoherence).

> Scientists do their work in a lab.
>
> [Re: A man who is visiting a forest, and has missed the baboon—How does he know if he‘s got/seen everything there?] I say he‘s one of the guys who‘s missed the baboon…He doesn‘t know what he‘s missed but he thinks to himself that he‘s seen everything so he‘ll just go (i.e., depart)…He‘ll tell people, ―This is what‘s in the forest so now you don‘t have to go," and then what if they, like, ―Oh, I think I‘ll just go and sit in a river and nothing‘s going to happen" and then a snake‘s in the river and then it bites you. And then they start this whole fight with each other…[So then someday someone might experience something that is different to what he told…] And then [they] told somebody…[Okay, so then it gets back to him, well, actually he got it wrong.
>
> Because they found bones and put them together so they knew what they looked like. And by their bones were healthy they were herbivores. Herbivores eat plants. Carnivores eat meat, but some might not be healthy meat. So strong bones might be herbivores.
>
> They look at the clouds to see if it will rain the next day. With a satellite in space they can see the climate.

Disagreements vs. One answer

According to Shanon, scientists disagree because they work in different ways and therefore reach different answers. However, she went on to say that the various different methods will all result in the same answer (System incoherence).

Different methods and different answers:

> [Re: Scientists‘ disagreements] They have different theories. They experiment differently with the bones and it gives them different answers.

All answers are ultimately the same:

> [Re: Scientists following a fixed set of steps] Well, it depends on what you‘re looking at,

> and it can be, but…if they take a dinosaur bone then you have to first dig it up, you know, but in some cases you can just choose where to start because it really doesn‘t matter ‗cos you‘re going to get there (i.e., to the answer) anyway.

Scientists know vs. God knows

Raashid described how scientists study things in the past, but that proof is required, rather than relying on guesswork. However, Raashid acknowledged that scientists were not there in the past and therefore they could be wrong. Either way, people cannot know for sure, as only God can tell us about the past (System incoherence).

Scientists need proof when they study the past:

> (Re: use of imaginations and creativity) Not when they discover history. You can‘t just take guesses and use your imagination. You need proof, for example, what people looked like. For example, not when they do investigations.
>
> They create and test stuff. They improve technology in the modern world. It also depends what section they do in science.
>
> They discover stuff that hasn‘t been discovered yet, and they discover history and create new things.
>
> I think because they are interested in making and discovering old or new things in the world.

Scientists would be wrong about the past—only God can tell:

> Because they all see it in a different way and only God can tell what [dinosaurs] really look like.

Raashid also said that scientists predict the weather by measuring water in millimetres, yet people cannot predict the future because only God knows (System incoherence).

Scientists predict the weather:

> [Re: weather predictions] By measuring water in millimetres (mm).

Only God knows about the future:

> You can‘t give an example of what is going to happen in the future because you don‘t know what is going to happen in the future. Only God knows.

Evidence-based science vs. Disbelief/doubt in scientists

According to Shanon, scientists‘ knowledge about dinosaurs is based on evidence such as fossils, and they are certain about this knowledge. Yet Shanon was unsuresure if she believed the scientists (System incoherence).

> They found fossils buried in the earth and bones had certain nutrients in them. I don‘t even know if I believe in dinosaurs—it‘s so long ago and it doesn‘t make an impact on our lives now…They are certain, I am not.

Shanon also stated that scientists check their results thoroughly in order to correct any mistakes before publicizing the result. However, she doubted the openness and credibility of scientists, saying that they might be dishonest for the sake of their own material gain (System incoherence).

Scientists could be bad people and corrupt:

[Re: Can we trust what scientists tell us] Sometimes: We don‘t know what goes on in their labs...We don‘t know what they use. For example, their cure for AIDS could just be water...Are they corrupt businessmen or truly good people trying to improve our lives?

> It could be like…if they could miss a fact and they could get something wrong and then if they go and sell the wrong idea to a big company that spreads it all over the world, and then suddenly you get people getting sick and stuff… Sometimes they can make an innocent mistake, and sometimes they can just be bad people, but hope not!

Scientists triple-check before publicizing their findings:

> …I‘m sure that a lot of scientists make mistakes all the time but then they don‘t go, they‘re not…scientists, they…triple check, they go over and over again just to make sure it‘s perfect, so if they do make mistakes, then hopefully they‘re gone over again and then they‘ll correct it before it gets out to us…

Samuel mentioned that scientists find fossils and bones (albeit incomplete skeletons), however, some scientists might think that dinosaurs are false (System complexity):

> [Re: Dinosaurs] They find bones and put them together to determine what they looked like on their teeth or mouth bones, there might be evidence to show what they ate.
>
> Some might think (for example) dinosaurs are fake and spend years investigating their opinion.

According to Dyllan, scientists conduct tests for aliens, and they sent the Voyager 1 to experience and take images of outer space. However, he went on to say that scientists are inaccurate in terms of what they report to us as their findings, and that he was unsure if scientists study space (System incoherence).

Scientists test for aliens:

> People sometimes think they found an alien in their house then scientists do tests on it to tell that person if it is an alien or not.

Scientists take pictures of outer space:

> They sent pictures, they sent, like, a Voyager out to space and, like, that took pictures of space, so that would give them idea of what it was like.

Scientists sent the Voyager to experience Space:

> Voyager 1 that was sent out so they can experience our solar system…

Scientists' report inaccurate findings:

> Say the Voyager 1 passed Pluto and now it's shut down, its not getting any sunlight and now it's travelling for a long time and there's a planet that looks similar to Pluto or maybe has the same structure as Pluto and now they get sunlight again and they say, ―Ah, it's just past Pluto, and it receives light from somewhere else." But it's not Pluto. It's like a different planet. Something like that.

Perhaps scientists don't study Space:

> …Space is Nature because it always was there, but they don't really study- they don't work with that, m'am, because they can't touch the planets, do you know what I mean, m'am?

Brian said it is not ―real science" if scientists create stories based on their own thoughts as opposed to checking what they say against the evidence that has been found. However, he also said that scientists will create stories in order to be considered the most clever or the most accurate (System incoherence).

Scientists' own thoughts and imaginations are not real science:

> …What [are] their stories…based on?] Mmm…I wouldn't [actually] know that…Maybe that's what they think, or like, maybe…if they think there's not gonna be global warming they just think that the sun will just miss Earth or something. [So it's just their ideas/their own thoughts… That's [not] still real science.] …Because they're just using their imag…'cos they're not actually thinking what *will* happen. Or what, or that's what they think but they don't actually check that…

Fictional stories that make scientists appear clever or correct:

> I think that they would make up stories so that people would think that they are clever...or right...

Brian also said that scientists might reach different answers from the same facts in order to achieve personal fame. However, he went on to say that scientists need to verify what they say before publicizing this knowledge, by using measurement instruments (System incoherence).

Scientists seek personal glory:

> [Re: Do you think that if all scientists have the facts they're going to come up with the same answers?] No, I think they will just make excuses to say that they are wrong, like, mmm, I don't know, I can't think of an [example of an] excuse. [It is just so that they can find out for themselves…so that they can be the ones to have the] glory or something…

Scientists use measurements/instruments to check what they say:

> …[They need to check their stories that they make up to tell us.] Mmm, maybe with a telescope then they can see how much degrees or something, that…I do *not* know…

According to Yamina, scientists are credible because their accounts are empirically-based (e.g., they study evidence such as bones and fossils, and use instruments such as machines, scanners, and thermometers). Therefore, scientists' knowledge about plants and animals can be trusted. However, Yamina also stated that some scientists are deliberately deceitful and therefore cannot always be trusted (e.g., meteor and baby dinosaur) (System incoherence).

> They use a machine to discover what the weather will be...It has the temperature in a box and then they‘ll open the box to see what the temperature will be.

> [They do their work] to find answers to the questions about the creature…what the creature probably looked like, how they lived, what they ate…in case something like that comes up in the future.

> [When they study fossils] maybe they will break it open and look at it and feel the different textures…[in the lab].

> They found and studied the bones and put them together and to find out what dinosaur it was and ate…To find out about skin colour they scan it into a machine and it tells them.

> [We can‘t always trust what scientists tell us because] they might think that you‘re a robber, and then they will tell you there‘s not a meteor coming, but then it really is coming, just to kill you and will say it‘s not coming in your area and its coming in some other area and the people are already evacuated and it‘s really coming to your area…[but the scientist won‘t also get killed] because he‘ll be gone already...[Or] you might have a baby dinosaur in his lab, and he‘ll say, ―No, it‘s just an experiment of some other creature," then you decide, ―okay, I‘m going to steal this creature and I‘m gonna sell it", but then it‘s really a dinosaur. And when it grows up it bites your head off and you die!...[But we can believe what scientists say] about the plants and animals fossils.]

Confirmed facts vs. Imagination/estimation

According to Shanon, scientists cannot simply imagine things, as they need to find the truth. Yet she also stated that science is not only based on facts (System incoherence).

> Scientists need to find the truth, not the imagination in their heads.

> It can be based on a belief, a term (such as a theory), an object (for example, a tree), a human (that is us!)—almost anything…[A term/theory is something that you‘re trying to prove yes, it‘s right or no, it‘s wrong].

Samuel said that scientists work with facts and not creativity, although sometimes scientists make estimates or take guesses (System complexity).

Scientists work with proven facts:

> They have to work with facts that have proven to be true. If they use their creativity the facts will not be true and their investigation will be made up...

Scientists sometimes guess/estimate:

> They research well, but sometimes guess or estimate. They discover stuff that *could* be true. *(italics added)*

> Scientists guess sometimes to fit in with their facts…If they find a dinosaur fossil but then they don‘t find one bone, they guess what it might look like. If you‘ve got a full skeleton and…you can see that one of their fingers are missing and you‘re looked around that square kilometre or whatever and you can‘t find it there, then they might just estimate or make up that bone just to complete it.

According to Gideon, myths are not part of science until they have been confirmed, yet he recognized that scientists use their imaginations in their work (e.g., dinosaurs). He also acknowledged the possibility that scientific knowledge could change in the future (System complexity).

Science is based on facts, not myths:

> Myths aren‘t part of science—only when they‘ve been confirmed.
>
> [Science is only based on facts.]

Scientists use their imaginations:

> [Scientists use their imaginations and creativity] when for example they put a dinosaur back together…You have no clue what it‘s going to look like. They use their imaginations to try lots of different ways until they get what they think the dinosaur looked like.

Scientific knowledge can change:

> For a very long time people have been talking about going to the moon, and it happened about twenty years ago, it happened about three years ago. So, I mean, the question is, was it or was it not a…myth before it happened? [And they say it‘s not possible now to live in space permanently but in the future it might be…] Is it a fact, or is it just a story…? [And with evolution, it is possible to evolve more still, but it‘s in the future and we don‘t know what‘s going to happen in the future…[That is not part of science] because I think that even if they tell us stuff now, I think there‘s a very good chance of it being different in the future…

Brian said that scientists try new inventions (i.e., robots) and new experiments (i.e., medicine) [evidence]. However, he did not acknowledge that scientists use their imaginations/creativity in their work, stating that that would be then be fiction (System incoherence).

Science includes new inventions:

> [Re: What kind of work do scientists do] It depends on what sort of science…They…try new inventions (i.e., robots), try new experiments (i.e., medicine), and find cures for illnesses.
>
> [Science is not only based on facts because] there are also inventions and discoveries from scientists..e.g., New planets, inventions, cures for illnesses. These are different to facts because facts just tell us about the object or something. Discoveries are something that no-one else knows about. Inventions are things you create (4.d. add.).

Imagination is fiction:

> Because when you use your imagination it is fiction.

In addition to the above instances of system complexity and system incoherence that were identified within the students‘ NOS views, there was also an instance of explicit conflict that emerged during a student‘s description of his ideas about science. This finding is presented next.

Explicit conflict

Dyllan articulated explicit conflict between what he is taught in science at school and what he is told by his parents at home. He chooses to believe his science teacher, but this discrepancy is confusing for him:

> [Re: Is what science tells you the absolute truth?] Mmm, no. M'am, because, why I say no, m'am, is because Mr. [B] says if I go out to space…swim in space…it's a pool. Then, Mr. [B] said I will see stars and I will see comets and I will see…maybe a dwarf sun or something like that, m'am. And then my Dad says different. He says if I go out to space I will just see blackness unless there is a planet in front of me. So that's why I say, m'am, I don't- you see, it's confusing like that, m'am…I would say that I believe Mr. [B], because if you look up you will see millions of stars so obviously if you go up to the stars it will be all around us…I believe Mr. [B], but, I don't believe that there's nothing there but planets. I don't believe that, m'am.

Furthermore, Dyllan's naïve view regarding the socially- and culturally-embedded aspect of NOS—specifically, that scientists shouldn't disagree about things—seems to stem from his personal experiences in having to possibly choose between what his science teacher tells him or what his Dad says, because this has direct implications for him when preparing for a test at school:

> [It's not really okay that scientists disagree about things] because…for instance, [if] I have a test. And my dad and I study for the test and I read out something that's given in our notes that we're gonna be tested on that says, [for example] that the Milky Way has twenty solar systems, and now my dad disagrees with that and he says it only has one. And then I write on my test ―one" and then I get marked wrong. And then that might just give me one mark off full marks, or I might fail because of that.

These various instances of system complexity and system incoherence, as well as explicit conflict within the students' NOS views, indicate that their students' views of NOS were only somewhat coherent.

To summarise, analysis of the students' NOS views revealed a unique NOS profile for each case, and that the students' understanding did not develop uniformly for all five aspects of NOS. Furthermore, the students' NOS responses were rich, and represented a range of views about each of the five aspects of NOS.

Part 2: Views of the natural world (i.e., Nature)

In examining the students' views of the natural world (a component of worldview [Chapter 2, page 30]), the researcher sought to determine how the students defined Nature, and, more specifically, how they viewed Nature in relation to each of the four worldview descriptions (i.e., epistemological, ontological, emotional and status descriptions). A comparison between individual students' worldview profiles was then made, and the overall coherence of the students' views of the natural world was determined.

Accordingly, the results in Part 2 are presented in regard to the students' definitions of Nature, the details of their views regarding each of the four worldview descriptions, a comparison of individuals' worldview descriptor combinations, and the internal coherence within students' worldview responses. Figure 4.4 presents a diagrammatic overview of the data that were collected and analysed concerning the students' views of the natural world, and the findings that such analyses yielded.

Definitions of the natural world

At first, when asked to explain their views of ―What is Nature?" (Chapter 3, page 89), the students described people as being separate from the natural world. Nature was depicted as living things which exist on their own (occurring naturally) without artificial intervention and before human impact. More specifically, the students stated that the natural world does not include technology or things that are man-made. Furthermore, students said that the natural world is not limited to things that are found on the Earth, as Nature also exists beyond Earth. These various components of the students' definitions of Nature are presented below, and illustrated with extracts from the students' responses.

Nature is living, not human, not man-made, separate from technology

Dan, Shanon, Yamina and Aamir defined Nature as things that are living (or once lived) and grow:

> Nature could be **living** creatures, and fire is Nature, animals are Nature, tornadoes are Nature, fruit is Nature. It is anything that pretty much grows on trees and is **living**. A fossil is part of Nature because **it was once a living creature**. And germs could be part of Nature because there could be germs on animals and in meat and then animals eat the meat and then they get germs. (Dan)

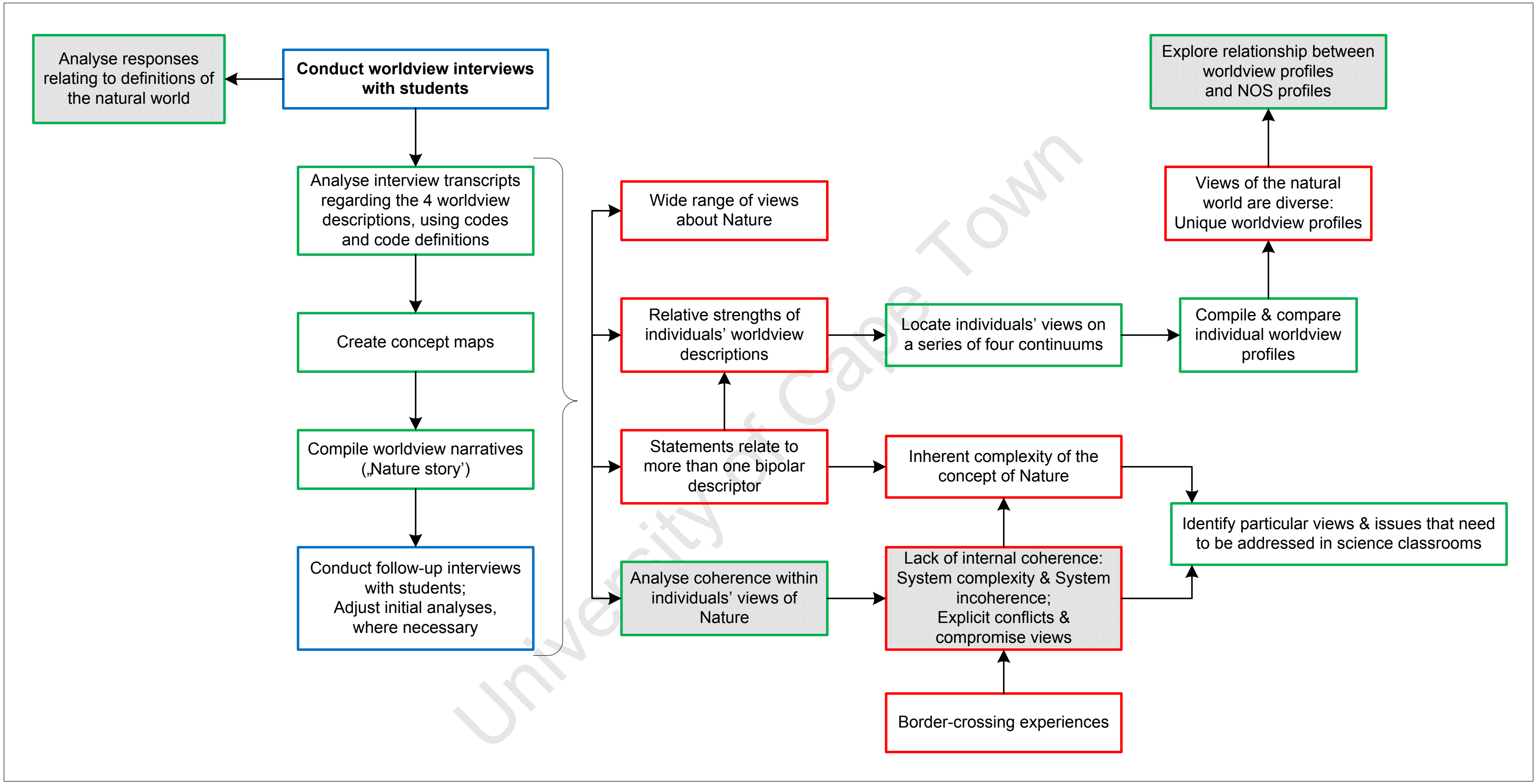
> Nature is things that **live** or that **used to live once**. (Shanon)

> Nature is **living things** that are on the Earth. <u>It wasn't just there</u>, but it **grows** and starts from small things and it just grew bigger and bigger and bigger. (Yamina)

> Nature is to do with **living** creatures. It is things that **grow**…I think all animals are part of the natural environment. (Aamir)

Aaeesha made a distinction between humans, and animals or plants. She also differentiated Nature from technology:

> There's a difference between humans and animals, and trees and humans. And Nature is things that don't use technology, like, they had to use a lot of technology to get the astronaut in space, so that's not part of Nature.



KEY: Blocks outlined in blue indicate data that were collected, blocks outlined in green indicate analyses that were conducted, and blocks outlined in red indicate results of the various analyses; Blocks shaded in *grey* signal analyses and results relating to *coherence* (these aspects are therefore also reflected in Figure 4.17 [page 179]).

Figure 4.4: Diagrammatic overview of the data collected concerning the students' views of the natural world, analyses that were conducted, and the results that these analyses yielded

Dan and Samuel also viewed Nature as being distinct from technology:

> …Nature will run out some day. In the future there‘s only gonna be- there‘s mainly gonna be technology and people won‘t think so much of Nature. They‘ll only think about technology in their modern day lives (Dan).

> I think in our modern time and age that **we use Nature too little**. We spend so much time with technology and on the computer, and watching tv. People go Ten-pin bowling and LaserQuest and watch movies every weekend. We should rather be outside playing and appreciate what Nature has to offer. (Samuel)

Dyllan distinguished Nature from technology and man-made things:

> The astronaut [is not part of Nature because] he‘s got lots of machines on his back and that‘s not part of Nature. It‘s man-made stuff…[The natural world isn‘t all there is because] there is also technology that we play with. We don‘t just play with Nature.

Brian, Shafia, Dyllan, Dan, Samuel, Shafia and Victoria also defined Nature as being that which is not made by man:

> The natural world was made by Nature so it is anything that has not been man-made. Humans are part of Nature, except for their clothes, because that‘s too technical. (Brian)

> We use the resources from Nature to make the man-made things [such as] cars and stuff…We can put Nature in man- made places, ‗cos in our house we can have a plant, we can have a waterfall, small fountain…and all these kind of stuff we can have… (Shafia)

> Nature is things that man didn‘t make. It has just been there all the time, like before we were born. (Dyllan)

> It‘s pure, because it‘s not made from something, it‘s original. (Dan)

> A Nature environment is outside where there‘s no civilization. We didn‘t do anything to make it. If we go and build on it then it‘s not Nature. (Samuel)

> …Nature‘s supposed to be something that‘s not man-made. And well, Nature‘s not, like inside the homes and stuff. Nature‘s outside. It‘s something that man never made…So it‘s away from man-made things… (Shafia)

> Nature is this that no-one built or put there. (Victoria)

According to Shanon, Samuel and Aamir, Nature is that which existed before man transformed it or processed it in some way:

> Nature is something that was there before man came and changed it. Like diamonds come from the ground, and they‘re mined, and taken through factories and polished. (Shanon)

> A Nature environment is outside where there‘s no civilization. We didn‘t do anything to make it. If we go and build on it then it‘s not Nature. For example, a diamond is part of Nature because it was from underground, but the shape isn‘t Nature because we probably shaped it by cutting it and making it look like a diamond. (Samuel)

> The natural world is things that are not man-made, but man processes some of the stuff. Like a diamond—it was there when the Earth was first made, but you have to mine it out first and cut it...But when it‘s in the Earth it‘s still part of the natural environment. (Aamir)

The following statement from Gideon indicates that he viewed Nature as that which occurs naturally as opposed to being man-made. Similar to Aaeesha, he was also perhaps making some distinction between natural beings and human beings, by stating that Nature doesn't have a human heart:

> Nature is anything that's created by the Earth, like sand, water, ice, wind, and plants, and it doesn't have a heart. (Gideon)

Maya described Nature as being ―naturally there", and Yamina described nature as a place where we can exist naturally (i.e., unsupported by unnatural technology):

> Nature is naturally there, like animals in the wild, and trees. But sometimes some people could plant things from Nature. Like obviously you can take the seeds from flowers and you can plant more. So one has to be there to make many, but it is just there. It's naturally there. The cows and the grass, for example, it's where they live and it's their nature. (Maya)

> [The astronaut in space is not Nature because] there's no air there for it to breathe, and, you can't walk in space, you have to float, and you can land upside down, and if you're upside down too long you can die. (Yamina)

According to Raashid, Nature is what God created, and includes things that existed before people inhabited the Earth:

> [Nature] is stuff which God created. It has been created at a certain time, so it was not always just there. God put it there. And new stuff can be created, like dinosaurs were created and then we came.

Nature is on Earth, and also beyond Earth

Students described Nature as being everywhere, and all around us:

> I think about Nature a lot because we are in it……It is all around us… (Victoria)

> …Nature is actually everywhere, like this wood (desk) is Nature. It was once Nature… (Dan)

> …Nature's all around you so you should know more about it… (Maya)

In fact, the entire world is made up of Nature:

> There's lot of different things that make up Nature: you can have water and you can have land, and rainforest, desert, and animals…**The entire world**'s made up from Nature. It's a whole big thing. And 80% of the world is sea. And that's basically Nature except, like, maybe ships and that. (Samuel)

Moreover, Nature is not only on Earth; it is also beyond Earth:

> Nature is things that are there on Earth, and it is also things in the galaxy or the universe. (Shanon)

> …But Nature is not only on the Earth, like the universe and the rest of the solar system is also part of Nature…The earth is Nature and also space and moons. (Victoria)

> The natural environment is around the whole universe… (Aamir)

In summary, the students defined Nature as living things that occur both on Earth and beyond the Earth, and which do not involve technology and man-made processes.

Four worldview descriptions

Rich data were collected of the students' views regarding four descriptions of the natural world, namely, epistemological, ontological, emotional and status descriptions (Chapter 3, page 85). Responses relating to each description were arranged into themes arising from the contents of the students' statements. Due to space restrictions, a snapshot is presented here of the results pertaining to each of the four worldview descriptions. Detailed data pertaining hereto (including illustrations from the students' original worldview narratives) are located in Appendix 4.3 (page 378).

Epistemological descriptions

The students drew on a variety of examples in describing their epistemological views of the natural world. Details of the range of knowable and unknowable examples they cited were organised according to four themes, namely: 1) Can we know things about Nature?, 2) Is Nature predictable?, 3) Is there order in Nature?, and, 4) Is there a reason for things that happen in Nature?

Can we know things about Nature?

The students' views relating to this first theme included responses that were both knowable and unknowable. Reponses that were knowable included statements that Nature is understandable, and that we can find out things about Nature (e.g., by means of observation and personal experiences in Nature, conducting research, consulting books and electronic media resources, at school, and by consulting parents and practitioners). Scientists were identified as the people who study Nature. Furthermore, students described a need to learn more about Nature (i.e., for survival, and in order to protect Nature, as well as in response to a need to know about the past, and to pass on existing knowledge to future generations) (Appendix 4.3, Table A4.3-1, page 378).

Responses that were unknowable, relating to the theme *Can we know things about Nature?*, included statements that Nature is diverse and comprises a mixture of different things, and that there are species in Nature that have yet to be discovered. Students described Nature as confusing, complicated and difficult to understand, and stated that it requires hard work and much time to learn everything about Nature. Furthermore, students described various changes that occur in the natural world (e.g., relating to the weather, climate change and natural disasters, seasonal changes and plant and animal life cycles, as well as small and large-scale transformative processes such as erosion, freezing and fire, and the Big Bang, evolution and continental drift, etc.) (Appendix 4.3, Table A4.3-1, page 378).

Is Nature predictable?

The students‘ responses concerning the predictability of Nature included a range of views, from unpredictable, to partly unpredictable and partly predictable, to predictable. Students typically referred to weather-related phenomena and natural disasters in illustrating their views. In some cases, students stated that an ability to predict Nature depends on human intellect, whilst others mentioned the use of satellites in making weather predictions. However, there were also statements that only God knows what will happen in the future (Appendix 4.3, Table A4.3-2, page 378).

Is there order in Nature?

Descriptions of Nature that were knowable, concerning order in Nature, included references to natural cycles (e.g., food chains, interdependence of species within ecosystems, plant and animal lifecycles) as well as references to cause-and-effect explanations. A view was also expressed that Nature is orderly until people intervene and disrupt the natural order. In contrast to these Knowable descriptions, there were students who described chaos and a lack of order in Nature. Examples of chaos included references to weather-related natural phenomena and natural disasters, and animals fighting over resources. Descriptions of a lack of order in Nature also concerned diversity in Nature, and the timing and locations of various natural events, as well as a reference to the unpredictability of Nature (Appendix 4.3, Table A4.3-3, page 378).

Is there a reason for things that happen in Nature?

Responses concerning the purposes or reasons for natural events and natural phenomena, which were knowable, included statements that everything on Earth has a reason/purpose, although the purpose might be unknown. Responses that were unknowable included statements that there is no reason for natural events, such as, for example, natural disasters (Appendix 4.3, Table A4.3-4, page 381). Students‘ statements concerning the reasons/purposes for natural events and phenomena were analysed not only in terms of ontological descriptions of Nature but also in terms of ontological descriptions of the natural world, as presented later (Chapter 4, page 148).

In summary, the students described a range of epistemological views of the natural world, which included statements about Nature that were knowable and unknowable.

Development of a Knowable-Unknowable continuum

The students typically included both examples that were both knowable and unknowable, when describing their views of the natural world, as illustrated in the following extract from Victoria‗s worldview narrative (Victoria). [Note: In order to facilitate the identification of knowable and unknowable portions of the narrative, selected knowable phrases are highlighted in bold, and selected unknowable phrases are underlined]:

> Nature does <u>change</u>, like when there are earthquakes and mountains form, and when tsunamis wash away some of the land and makes a heap there and it‘s smooth somewhere else…You <u>can‘t always predict</u> what will happen in Nature, like sometimes with the weather there are clouds coming, but yet it still doesn‘t rain. Sometimes there is <u>chaos</u> in Nature, like when wildfires start and everybody rushes around and the trees are blazing. It makes a noise and the animals get scared...But **things happen in Nature for a reason**…let‘s say a bird eats a worm and that worm has died, and you think ―Oh shame, poor worm," but then the bird might have been a very starving creature and need food, and the worm happened to be there. So it happened for a **purpose**. It‘s **orderly**, how things work in Nature, with a **system**, and it knows what it‘s doing. Nature is <u>complicated</u> in some ways, the way some things work to get how they are. Like a seed, it doesn‘t just go, just pop in the ground, you water it and then ―Wow!" You have to look after it and it grows in certain stages and steps. You can sometimes get <u>confused</u> by Nature because it is <u>complicated</u> and because it <u>changes</u> in so many ways. But **most of Nature is understandable** because of the **system**, as things do things in certain ways. Flowers bloom in a certain way. You can see it unravelling slowly, slowly, until it‘s a beautiful flower, and you can **understand** it. Nature is a very interesting thing and we can **find things out** by doing research and studies…**Finding out** things about Nature gives us **a better understanding** of why they are there, and so we **know**. Specific people, mostly scientists, do this kind of work. But we don‘t really need to study Nature or to learn more about it, otherwise it might just take away the lust to be in Nature. <u>It‘s nice to have some mysteries unsolved</u> just to keep it fascinating. Nature is <u>mysterious</u>, like, how does the ice stay ice even though the sun comes down on it?...It is <u>mysterious</u> even though we are used to it…

It also became apparent that there were variations in the strength of students‘ worldviews, that is, the extent to which each student‘s epistemological views were aligned with a particular descriptor overall (e.g., knowable or unknowable). Stated differently, some students held views that were strongly knowable (e.g., Brian), whilst other students held views that were knowable but included a number of unknowable descriptions (e.g., Aamir). Similarly, some students held strongly unknowable views (e.g., Gideon), whilst in other cases there were a number of knowable descriptions included in students‘ unknowable views (e.g., Raashid). Therefore, in addition to classifying each case in terms of a bipolar descriptor overall (i.e., knowable, unknowable), the strength of each student‘s views was determined (e.g., knowable or strongly knowable). To this end, a continuum was developed in order to reflect a more subtle variation amongst the strengths of students‘ bipolar epistemological classifications (Figure 4.5).

At the one end of a continuum, strongly knowable worldview descriptions (K++) included views that we can learn and know things about Nature, Nature is understandable and can be explained, we can observe things in Nature and do research, Nature is not complicated, it does not change and it is predictable, things happen in an order or cycle in Nature, and there is a reason/purpose for things natural events and phenomena. In contrast, on the opposite end of a continuum, strongly unknowable worldview descriptions (U++) included views that there are things we don‘t know and haven‘t yet discovered in Nature; Nature is mysterious, complicated, confusing and difficult to understand; Nature is diverse and comprises a mixture of different things; it changes and is unpredictable; Nature is not orderly; and there is no reason for things that happen in Nature. Between these two poles were located views that were knowable (K+U), and unknowable (K–U+). One student‘s epistemological views were partly knowable and partly unknowable (K/U) and therefore he was located in the middle of the continuum (between knowable and unknowable).

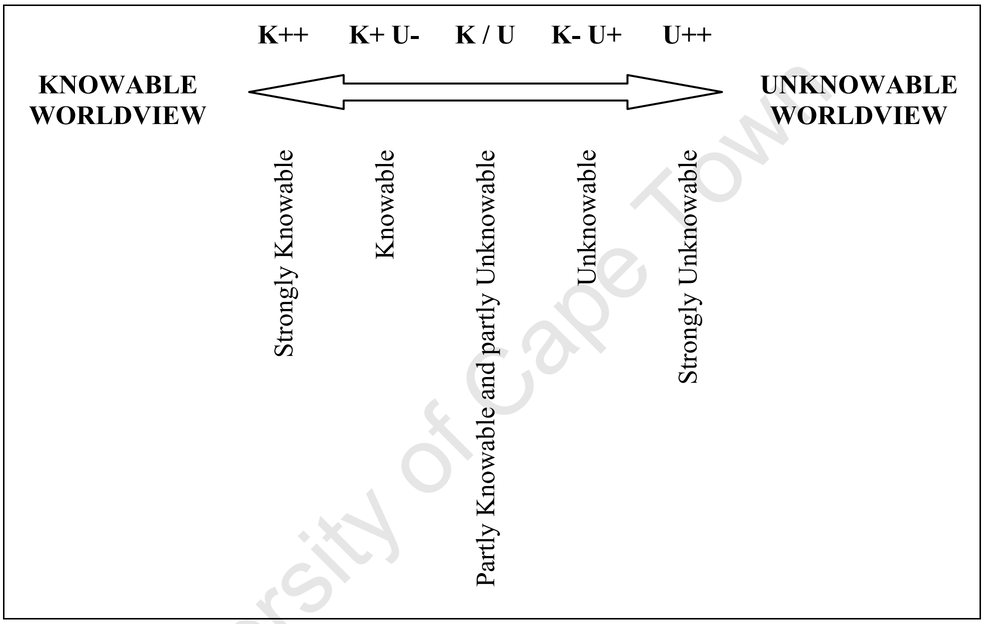


Figure 4.5: Continuum reflecting the relative strengths of the students‘ epistemological worldview descriptions

At the one end of a continuum, strongly knowable worldview descriptions (K++) included views that we can learn and know things about Nature, Nature is understandable and can be explained, we can observe things in Nature and do research, Nature is not complicated, it does not change and it is predictable, things happen in an order or cycle in Nature, and there is a reason/purpose for things natural events and phenomena. In contrast, on the opposite end of a continuum, strongly unknowable worldview descriptions (U++) included views that there are things we don‘t know and haven‘t yet discovered in Nature; Nature is mysterious, complicated, confusing and difficult to understand; Nature is diverse and comprises a mixture of different things; it changes and is unpredictable; Nature is not orderly; and there is no reason for things that happen in Nature. Between these two poles were located views that were knowable (K+U), and unknowable (K–U+). One student‘s epistemological views were partly knowable and partly unknowable (K/U) and therefore he was located in the middle of the continuum (between knowable and unknowable).

Each of the fourteen cases were located at a position on a continuum, according to the relative weighting of the various knowable and unknowable views that constituted their epistemological worldview descriptions. For example, Brian's view of the natural world was classified as strongly knowable (K++) (Figure 4.6). Details of the remaining cases—located at each of the various positions on a Knowable-Unknowable continuum—are provided in Appendix 4.4 (page 393).

Knowable responses:	**K++**	**K+ U-**	**K / U**	**K- U+**	**U++**	**Unknowable responses:**
We can know and understand things in Nature Nature is not confusing or mysterious Most things in Nature have been found Nature is predictable Nature should be studied We can do experiments and we can test for cures Scientists discover Nature and they have explanations for why things happen	**Strongly Knowable**	**Knowable**	**Partly Knowable and partly Unknowable**	**Unknowable**	**Strongly Unknowable**	There is diversity in Nature Nature grows everywhere and not in orderly rows

Figure 4.6: Overview of the contents of Brian's epistemological worldview descriptions

Overall, it was found that the fourteen students studied described diverse epistemological views of the natural world, of varying strengths, and therefore cases were positioned at all five locations on the knowable-unknowable continuum (Table 4.11).

Table 4.11: Locations of the students' epistemological worldview descriptions on the Knowable-Unknowable continuum (see Appendix 4.4, page 393)

K ++ Strongly knowable	**K + U -** Knowable	**K / U** Partly knowable, partly unknowable	**K – U +** Unknowable	**U ++** Strongly unknowable
Brian	Aamir Aaeesha Dan Maya Samuel Victoria Yamina	Dyllan	Raashid Shafia Shanon	Gideon Reza

Two observations can be made from the above table. First, eight of the fourteen cases are located on the knowable end (as opposed to the unknowable end) of the knowable-unknowable continuum, and predominantly at the knowable position (K+U-). Second, the majority of cases held epistemological views that included both knowable and unknowable descriptions, as evidenced by the eleven cases whose views were either knowable (K+U-), partly knowable and partly unknowable, or unknowable (K-U+) (as opposed to strongly knowable [K++] or strongly unknowable [U++]).

In summary, the students articulated a range of epistemological descriptions of the natural world, which typically included both knowable and unknowable descriptions. A knowable-unknowable continuum was therefore developed to reflect the relative strengths of the students' epistemological views. Cases were located at each of the five positions on this continuum, although a large number of the students held knowable views.

Ontological descriptions

The students drew on a variety of examples in describing their ontological views of the natural world. The range of naturalistic and super-naturalistic statements were organised according to seven themes, namely, (1) What is the origin of Nature?, (2) Is Nature holy and spiritual?, (3) Is there a purpose for things that happen in Nature?, (4) What are the processes that occur in Nature?, (5) Can we see and touch things in Nature?, (6) Is there transcendental involvement in Nature?, and, (7) Is Nature an animate being with a personality?

What is the origin of Nature?

In all cases, except one, students held the view that God created Nature, although two students expressed some uncertainty about this view. That said, however, students also talked about things being ―created by Nature" (e.g., Brian, Dyllan), and said that ―Nature...controls itself" (Gideon) (Appendix 4.3, Table A4.3-5, page 381).

Is Nature holy and spiritual?

On the one hand, students' descriptions of Nature as holy were related to God having created the Earth, and an acknowledgement that in some cultures, for example, the cow is considered to be holy. However, some students stated that they did not worship anything/anyone other than God. Holiness was also related to reverence and respect for dominant species in Nature (e.g., the lion as king of the jungle). On the other hand, views that Nature is spiritual were justified by a belief that God created it. References to spirituality in Nature also concerned the use of herbs for healing purposes and descriptions relating to an enjoyment of Nature (e.g., that Nature has a calming effect on some people). In contrast, however, there were students who said that the natural world is not spiritual because spirituality was associated with performing cultural rituals (e.g., sacrificial ceremonies and tribal dances) (Appendix 4.3, Table A4.3-6, page 382).

Is there a purpose for things that happen in Nature?

Students described Naturalistic and Super-naturalistic views relating to the theme of whether or not there is a purpose for things in Nature. Super-naturalistic views included statements that God controls natural events and that natural disasters, for example, are a form of punishment from God for people‘s wrongdoings. In contrast, a number of students described physical reasons for events in Nature. These naturalistic views included references to dynamic ecosystems and the interrelationships between the various components therein (Appendix 4.3, Table A4.3-7, page 383).

What are the processes that occur in Nature?

Further to the students‘ views regarding the purposes of natural events, various processes occurring in Nature were typically explained in terms of naturalistic causes (e.g., the formation of mountains, and changes in the weather) (Appendix 4.3, Table A4.3-8, page 383).

Can we see and touch things in Nature?

The students typically described Nature as something physical, that is, the natural world comprises living things, which can be experienced using our physical senses (e.g., sight, smell, hearing, and touch). This said, however, students also provided examples of that which cannot be seen or touched in Nature, such as, air and tiny molecules (e.g., germs) and parts of Nature that are too vast, too distant or too dangerous to be touched (Appendix 4.3, Table A4.3-9, page 384).

Is there transcendental involvement in Nature?

In contrast to students‘ descriptions of things in Nature that can be experienced and/or observed physically, four students gave examples of super-naturalistic elements in Nature. These references included super-natural places (e.g., Heaven and hell), super-natural beings (e.g., ghosts, the devil), and super-natural events (e.g., the Last Day of Judgment) (Appendix 4.3, Table A4.3-10, page 384).

Is Nature an animate being with a personality?

One student described a personified view of Nature as a sentient being with its own power and benevolent intentions. However, other students expressed the view that Nature does not have its own thoughts or emotions (Appendix 4.3, Table A4.3-11, page 384).

In summary, the students‘ ontological descriptions included a variety of examples relating to a range of naturalistic and super-naturalistic views of the natural world.

Development of a Naturalistic—Super-naturalistic continuum

As was the case with the students‘ epistemological descriptions of the natural world, it was found that the students‘ ontological worldview descriptions typically included examples of both naturalistic and super-naturalistic views of Nature, as illustrated in the following extract from Maya‗s worldview narrative. [Note: In order to facilitate the identification of naturalistic and super-naturalistic portions of the narrative, selected naturalistic phrases are highlighted in bold, and selected super-naturalistic phrases are underlined]:

> …Nature wasn‘t just there before, there was nothing, because <u>*Hashem* created it</u>. But it is <u>spiritual</u>, and it is powerful because <u>*Hashem* created it</u>…After Nature was <u>created</u>, **it's just doing its own thing**. To me, **Nature isn't holy**, because to our **religion the only thing that's holy is actually *Hashem***, God. It is amazing how <u>*Hashem* can make</u> something so powerful and strong without Him doing anything. <u>He made it</u>. It‘s not doing it Himself. It‘s just there…**Nature is naturally there**…The cows and the grass, for example, **it's where they live and it's their Nature**. Some have been there for a long time, like the fossil. And it is **things that happen naturally** like floods caused by tsunamis and earthquakes and things to make the sea do a big wave and then it comes and floods, or just lots of rain. Half of Nature you can see and touch, like, wind you can‘t touch and you can‘t see, but you can feel it, so you know it‘s there…Nature‘s all around you…Some things are in order in Nature, like rain, and the seasons are in a cycle. **There's always something to make something happen in Nature**.

As with the previous worldview description (i.e., epistemological), there were variations in the strength of the students‘ ontological worldview descriptions, that is, the extent to which each student‘s ontological views were aligned with a particular descriptor overall (e.g., naturalistic or super-naturalistic). On the one hand, some students held strongly naturalistic views despite their belief that God created Nature (e.g., Aamir). However, there were students who described views that were naturalistic but included some super-naturalistic descriptions (e.g., Brian). On the other hand there were students who held strongly super-naturalistic views (e.g., Reza), as well as other cases where there were a number of naturalistic descriptions included with the students‘ super-naturalistic views (e.g., Aaeesha). Therefore, in addition to classifying each case in terms of a bipolar descriptor overall (i.e., naturalistic, super-naturalistic), the strength of each student‘s views was determined (e.g., super-naturalistic or strongly super-naturalistic). To this end, a second continuum was developed (Figure 4.7), which reflects the subtle variations amongst the strengths of students‘ bipolar ontological classifications.

At the one end of a continuum, strongly naturalistic worldview descriptions (N++) included views that Nature is not holy or spiritual, things in Nature are created by Nature and Nature runs itself, natural events take place for physical purposes or they lack a purpose, natural

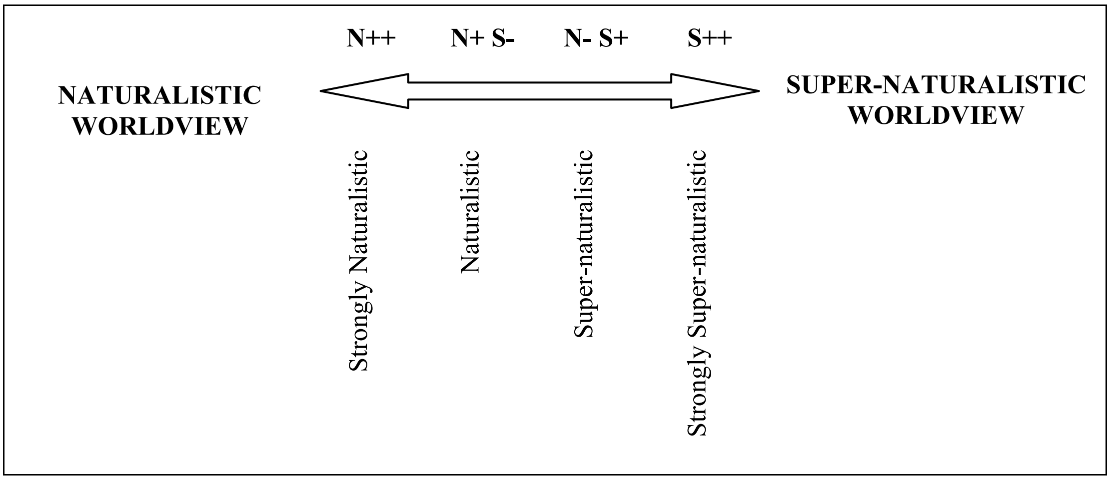


Figure 4.7: Continuum reflecting the relative strengths of the students' ontological worldview descriptions

events/phenomena are caused by physical processes, Nature is not a being, as well as a doubt in religious teachings. In contrast, on the opposite end of a continuum, strongly super-naturalistic worldview descriptions (S++) included views that Nature is created by God, it is holy and spiritual, there are super-naturalistic purposes for events in Nature, there is transcendental involvement in Nature, Nature is an animate being that acts with intention, as well as declarations of a preferred belief in God and/or religious teachings over other explanations about the natural world. Between these two poles were located views that were naturalistic (N+S-) and super-naturalistic (N–S+).

Each case was located at a position on a continuum, according to the relative weighting of the various naturalistic and super-naturalistic views that constituted the individual's ontological worldview description. For example, Aamir held a strongly naturalistic view (N++) of the natural world (Figure 4.8). Details of the remaining cases—located at each of the various positions on the Naturalistic—Super-naturalistic continuum—are provided in Appendix 4.5 (page 396).

Overall, the fourteen students described diverse ontological views of the natural world, and cases were positioned at all four locations on the naturalistic-super-naturalistic continuum (Table 4.12). Notably, a large number of the students' ontological views were located on the super-naturalistic end (as opposed to the naturalistic end), and specifically at the super-naturalistic position (N-S+). Also, the majority of the students' views included both naturalistic and super-naturalistic descriptions, as evidenced by the eleven cases whose views were either naturalistic (N+S-) or super-naturalistic (N-S+) (as opposed to strongly naturalistic [N++] and strongly super-naturalistic [S++] views).

Synopsis of Naturalistic responses:	N++	N+ S-	N- S+	S++	Synopsis of Super-naturalistic responses:
Nature is not holy or spiritual: I do not worship Nature If I need quietness I don‘t go and read a book under a tree Floods are caused by the moon, tsunamis are caused by unstable plates in the Earth Living and growing (cannot see air, germs, dead people)	**Strongly Naturalistic**	**Naturalistic**	**Super-naturalistic**	**Strongly Super-naturalistic**	God made it

Figure 4.8: Overview of the contents of Aamir‘s ontological worldview descriptions

Table 4.12: Locations of the students‘ ontological worldview descriptions on the Naturalistic—Super-naturalistic continuum (see Appendix 4.5, page 396)

N++ Strongly naturalistic	N+S - Naturalistic	N– S+ Super-naturalistic	S++ Strongly super-naturalistic
Aamir	Brian	Aaeesha	Reza
	Dan	Dyllan	Yamina
	Gideon	Raashid	
	Maya	Samuel	
		Shafia	
		Shanon	
		Victoria	

Negotiating contrasting explanations about Nature (Naturalistic vs. Super-naturalistic)

In six of the total fourteen cases, there was evidence of students negotiating differences between naturalistic and super-naturalistic explanations of the natural world. Four of these students held super-naturalistic worldviews (Dyllan, Shafia, Shanon, Victoria), but two students‘ worldviews were naturalistic overall (Brian, Gideon). Furthermore, these cases included students with various religious affiliations (i.e., three Christian students, two Jewish students, and one Muslim student). In four cases, students articulated explicit conflicts between their religious beliefs and science (Brian, Dyllan, Shafia, Shanon). In attempting to make sense of their perceived conflicts, three students preferred to hold onto their religious beliefs more strongly (Brian, Dyllan, Shanon), one student described mistrust in scientists (Dyllan), others expressed doubt in their religious teachings (Gideon, Victoria), and still others were unable to choose between the two (Shanon) or thought that perhaps both could be correct (Shafia). There were also two cases where students did not articulate explicit conflicts between science and religion, but they made attempts to reconcile naturalistic and super-naturalistic explanations of natural phenomena (Gideon, Victoria). Further details concerning these six students negotiating differences between naturalistic and super-naturalistic explanations of Nature (and conflicts between science and religion) have been included in a later section, which deals with the internal coherence within the students‘ views of the natural world (page 194).

In summary, the students articulated a range of ontological descriptions of the natural world, which typically included both naturalistic and super-naturalistic descriptions. A naturalistic—super-naturalistic continuum was therefore developed. This enabled cases to be located at various positions, which reflected the relative strengths of their ontological views. A large number of students held super-naturalistic worldviews. Furthermore, in describing their ontological views of the natural world, a number of students recognised differences between naturalistic and super-naturalistic explanation of Nature, and, more specifically, conflicts between science and religion.

Emotional descriptions

The students‘ emotional responses tended to reflect examples that mirrored the contents of some of the images of the worldview collage (e.g., references to kittens/puppies, bananas, fossils, diamonds, the desert, icebergs, volcanoes and tornadoes) (see Chapter 3, page 88: Figure 3.7). However, there remained diversity amongst the students‘ emotional views, as well as amongst the examples they chose to mention in describing their views. The various emotional responses were organised according to three themes, namely, (1) Is Nature enjoyable and appealing?, (2) Is Nature interesting?, and, (3) Is Nature dangerous, destructive and frightening, or is it peaceful and helpful?

Is nature enjoyable and appealing?

The students described various things that they enjoy—and do not enjoy—about Nature. Positive descriptions included references to animals and plants, places, and activities in Nature that are likeable and enjoyable. Students also described how Nature improves people‘s quality of life. There was one student, however, who expressed a dislike for Nature on the grounds that, for example, activities in natural settings are better suited to girls rather than boys. Positive emotional descriptions further included examples of plants, natural environments, natural events, and products of Nature that are beautiful, as well as examples of delicious foods (e.g., fruit) from Nature. Some students appreciated the variety of colours found in Nature, although one student felt that Nature was too colourful (Appendix 4.3, Table A4.3-12, page 385).

Is Nature interesting?

Students expressed amazement about natural processes (e.g., the formation of diamonds) and large-scale natural phenomena (e.g., tornadoes). They were also amazed by the diversity of and intelligence of species found in Nature, as well as by the provision of natural resources for people to use. Students expressed interest in learning about Nature, and in particular, discovering new animals. However, one student felt that some mysteries should remain unsolved in Nature in order to maintain people‘s enjoyment and interest in Nature. In contrast to these positive views, one student described Nature as boring, as it was something that he saw everyday. In line with this view, there were students who described that, due to their familiarity with everyday Nature and the fact that Nature can be found everywhere, they regarded it as ordinary (Appendix 4.3, Table A4.3-14. page 387).

Is Nature dangerous, destructive and frightening, or is it peaceful and helpful?

The students‘ Negative views of Nature as dangerous and frightening, were illustrated by a range of examples that included plant and animal species, natural disasters and weather-related phenomena that are harmful and may cause death. Some students associated danger with being in the wrong place at the wrong time, as they said that Nature is not intentionally malevolent towards people. Indeed, some students described the natural world as being helpful and good—whilst also citing examples of ―dirty" elements in Nature (e.g., maggots and germs) (Reza). That said, however, a number of students described Nature as being peaceful and relaxing, where the positive emotional effects of Nature could be experienced by spending time in natural places and engaging in relaxing activities in Nature (Appendix 4.3, Table A4.3-15, page 388).

In summary, the students articulated positive, neutral and negative emotional responses to the natural world, and they provided varied examples to support this range of emotional descriptions of Nature.

Development of a Positive-Negative continuum

As was the case with the students‘ epistemological and ontological descriptions of the natural world, it was found that the students‘ emotional worldview descriptions typically included examples of positive, neutral and negative views of Nature, as illustrated in the following extract from Gideon‗s worldview narrative. [Note: In order to facilitate the identification of positive, neutral and negative portions of the narrative, selected positive phrases are highlighted in bold, neutral phrases are in italics, and selected negative phrases are underlined]:

> Volcano eruptions, tornadoes, and fires…Nature can create stuff that‘s pretty <u>powerful</u> and <u>destructive</u>, <u>dangerous</u>. They‘re **cool**, but when they‘re actually chasing you it‘s not so much fun. Volcano eruptions, it‘s natural and **beautiful**, but it‘s <u>deadly and dangerous</u>. It‘s the same as the tornado, it looks kind of **nice** when you look at it from a distance, but if it‘s coming at you…it‘s kind of <u>scary</u>! There are only two parts about Nature that‘s <u>dangerous</u>, that‘s explosions which is fire, or kind of <u>destruction</u> would be by tornado. Other parts of

> Nature are *not dangerous*. Sand *isn't dangerous* <u>unless</u> you're caught in a sandstorm. Plants are *not dangerous* at all. It **wouldn't be frightening** just sitting on a beach where there's sand and water. So Nature is a mixture of many different things.

Furthermore, there were found to be variations in the strength of the students' emotional worldview descriptions, that is, the extent to which each student's emotional views were aligned with a particular descriptor overall (e.g., positive or negative). Specifically, some students held views that were strongly positive (e.g., Raashid), whilst other students held views that were positive but included a number of negative and neutral descriptions (e.g., Aaeesha). Similarly, one student held a strongly negative view (i.e., Aamir), whilst in other cases there were a number of positive and neutral descriptions included in students' negative views (e.g., Brian). Therefore, in addition to classifying each case in terms of a bipolar descriptor overall (i.e., positive, negative), the strength of each student's views was determined (e.g., positive or strongly positive). To this end, a third continuum was developed (Figure 4.9), which reflects a more subtle variation amongst the strengths of students' bipolar emotional classifications.

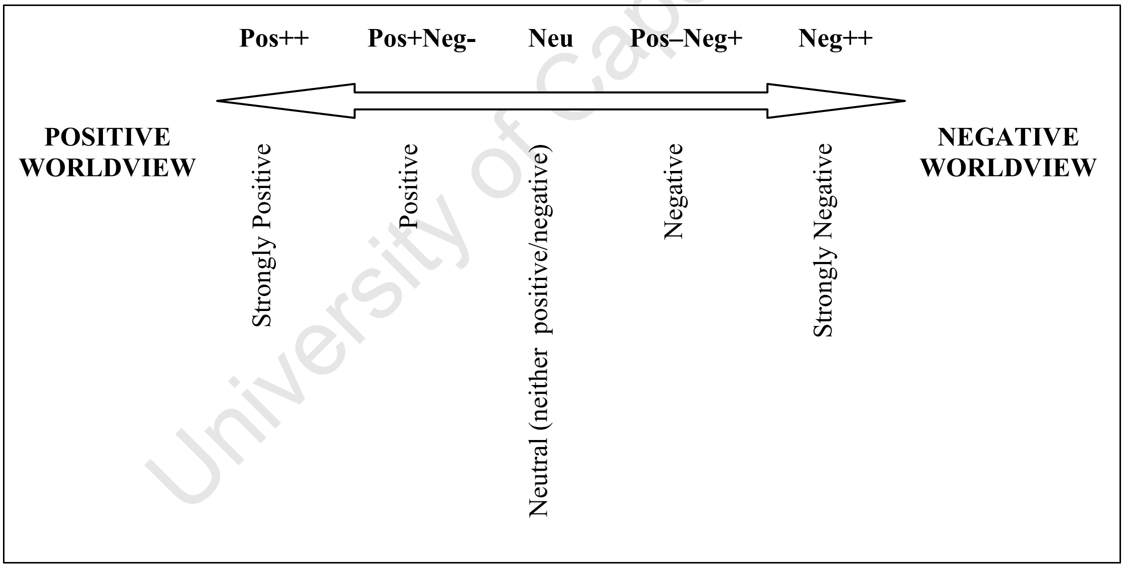


Figure 4.9: Continuum reflecting the relative strengths of the students' emotional worldview descriptions

At the one end of a continuum, strongly positive worldview descriptions (Pos++) included views that Nature is enjoyable and likeable; it is beautiful, colourful and delicious; Nature is amazing and fascinating; it is peaceful and relaxing to be in Nature; Nature is helpful and good; and thinking about Nature a lot. In contrast, on the opposite end of a continuum, strongly negative worldview descriptions (Neg++) included views that Nature is unappealing and boring; Nature is dangerous and destructive, and frightening; Nature can hurt things and it kills; Nature is not peaceful; Nature is not pure or clean. Between the two poles were located views that were positive (Pos+Neg-) and negative (Pos–Neg+). That is, positive worldviews are those which included an additional negative description, for example, a frightening or dangerous aspect of Nature. In cases where a positive worldview included a negative example, but the negative description was neutralised by a positive statement, the student‘s worldview was regarded as being strongly positive. For example, when considering whether or not Nature is dangerous and hurtful, Victoria described how Nature does not —come out and hurt you on purpose", and Shanon described how Nature can be dangerous —if you do something in the wrong way" or if you are —in a place at the wrong time". In addition to phrases that had a neutralising effect, there were responses that were neither positive nor negative, and these were regarded as neutral (Neu). For example, Nature is ordinary and part of everyday life; Nature is not dangerous and frightening; not really thinking about Nature a lot. One student‘s emotional description was neither positive nor negative overall, therefore a continuum was expanded to include a neutral position (Neu) in which this case could be located.

Each case was located at a position on a continuum, according to the relative weighting of the various positive, negative, and neutral views that constituted the individual‘s emotional worldview description. For example, Victoria held a strongly positive view of the natural world (Figure 4.10). The remainder of the cases—located at each of the various positions on the Positive-Negative continuum—are provided in Appendix 4.6 (page 398).

Synopsis of Positive responses:	**Pos ++**	**Pos + Neg -**	**Neu**	**Pos – Neg +**	**Neg ++**	**Synopsis of Negative responses:**
Nature is beautiful I enjoy going on trips around Nature, it is fun to play in Nature Nature is a very interesting thing and fascinating, which makes me enjoy it even more Nature is not dangerous or frightening Nature is not malicious—it tries to help you, and gives warnings If you are surrounded by Nature only, you feel calm I think about Nature a lot because we are in it	**Strongly Positive**	**Positive**	**Neutral (neither positive/negative)**	**Negative**	**Strongly Negative**	Animals get scared by the noise that a fire makes

Synopsis of Neutral responses:

Nature is all around us, everyday so, it might be ordinary for the people who live in that spot

Figure 4.10: Overview of the contents of Victoria‘s emotional worldview descriptions

Overall, the students described diverse views of their emotional responses to Nature, and cases were positioned at all five locations of the positive-negative continuum (Table 4.13).

Table 4.13: Locations of the students' emotional worldview descriptions on the Positive-Negative continuum (see Appendix 4.6, page 398)

Pos++ Strongly Positive	**Pos+ Neg-** Positive	**Neu** Neutral (neither Positive nor Negative)	**Pos– Neg+** Negative	**Neg++** Strongly Negative
Raashid Shanon Victoria Yamina	Aaeesha Dan Gideon Maya Samuel Shafia	Reza	Brian Dyllan	Aamir

Three observations can be made from Table 4.13. First, the majority of the students held emotional views of the natural world that were located on the positive end (as opposed to the negative end) of the positive-negative continuum. Second, the three cases who described views located at the Neutral position and towards the negative end of a continuum (i.e., neutral [neither Pos./Neg.], negative [Pos-Neg+] and strongly negative [Neg++]) were all boys. Third, a large proportion of the cases included both positive and negative descriptions in articulating their emotional views of the natural world, as evidenced by the nine cases whose views were either positive (Pos+Neg-), neutral (neither Pos./Neg.) or negative (Pos-Neg+) (as opposed to strongly positive [Pos++] or strongly negative [Neg++]).

In summary, the students articulated a range of emotional descriptions of the natural world, which typically included both positive and negative descriptions. A positive-negative continuum was therefore developed, to reflect this range of views. There were found to be cases located at each of the five positions on the continuum, although the majority of cases were located near the positive end.

Status descriptions

Students drew on a variety of examples in describing their status views of the natural world. Details of the range of resource-oriented and conservationist responses they cited were organised according to seven themes, namely, (1) Is Nature useful, and do we need it?, (2) How and why do we need to protect Nature?, (3) Is Nature over-used?, (4) Is Nature ruined?, (5) Do we need to be concerned about pollution in Nature?, (6) What impact does man have on the natural environment?, and (7) Can Nature be repaired/restored?

Is Nature useful? Do we need it?

In all the cases, the natural world was described as something that is useful and necessary for people. Various reasons for the useful of Nature included examples relating to survival in general, as well as food and drink, water and air, fire and fuel, clothing and building materials, medicine, relaxation and entertainment. Moreover, some students stated that the purpose of Nature being created was that people use it (Appendix 4.3, Table A4.3-16, page 389).

How and why do we need to protect Nature?

In addition to describing ways in which Nature can be used (i.e., Resource-oriented views), students described a need to protect Nature. These conservationist views were motivated by a need to prevent the destruction and/or extinction of Nature, and to sustain the natural resources needed for survival. Students described a link between learning about Nature and protecting it (i.e., there is a need to learn about Nature in order to be able to protect it, and there is a need to protect Nature so that there remains something for people to study). Students also identified ways in which Nature can be protected such as, for example, through Nature parks, recycling and not littering, although one student said that the natural world can only be protected by God (Appendix 4.3, Table A4.3-18, page 390).

Is Nature over-used?

According to some resource-oriented views described by students, Nature is not over-used, nor will it come to an end. This is because people look after the natural world and they do not use everything in Nature. In contrast, conservationist views regarding Nature being over-used included examples such as deforestation, over-fishing, poaching, and using too much water and fuel (e.g., petrol, coal). Some students pointed out that Nature has become over-used in recent years (Appendix 4.3, Table A4.3-19, page 390).

Is Nature ruined?

According to some students, the natural world is not ruined. These resource-oriented views included statements relating to the resiliency of Nature. However, some students viewed Nature as being partly ruined, and they distinguished between, for example, the sea being ruined but not the land. In contrast to views of Nature being resistant to damage, there were students who described Nature as being ruined. Examples of how Nature is were similar to those relating to the over-use of natural resources (i.e., deforestation, the killing of animals) as well as ozone layer damage and building developments that ruin natural land spaces (Appendix 4.3, Table A4.3-20, page 391).

Do we need to be concerned about Nature?

Students' conservationist views included concerns about the natural environment that were related to their descriptions of Nature being ruined, and their views that some of Nature is endangered and becoming extinct. Students expressed concern that continued pollution and the over-use of natural resources will eventually destroy the Earth (Appendix 4.3, Table A4.3-21, page 391).

What impact do people have on the natural environment?

Conservationist views included descriptions of various ways in which people's interactions with Nature have left a negative impact on the natural world (e.g., problems related to global warming, the destruction of habitats and ecosystems, and the abuse of natural resources). However, one student noted that while some people's actions are destructive, other people aim to help Nature (Appendix 4.3, Table A4.3-22, page 391).

Can nature be repaired/restored?

On the one hand, students described how the natural world can be restored, saying that Nature repairs itself (e.g., plants re-grow). Some students pointed out that Nature can only be repaired over time. On the other hand, students also described how the natural world cannot be repaired. Examples of irreparable damage included extinct animal species, the damaged ozone layer, and destruction resulting from volcanoes and floods. One student mentioned that science plays a role in repairing Nature, whilst another student stated that Nature cannot be repaired unless it is the will of God (Appendix 4.3, Table A4.3-23, page 392).

In summary, students' status descriptions included varied examples, which were related to a range of Resource-oriented and Conservationist views of the natural world.

Development of a Resource-oriented—Conservationist continuum

As was the case with students' epistemological, ontological and emotional descriptions of the natural world, it was found that students' status descriptions typically included examples of both resource-oriented and conservationist views of Nature. This is illustrated in the extract from Aaeesha‗s worldview narrative, below. [Note: In order to facilitate the identification of resource-oriented and conservationist portions of the narrative, selected resource-oriented phrases are highlighted in bold, and selected conservationist phrases are underlined]:

> …We **need** Nature for our everyday life so it is not just there. It serves as a purpose. We can **do** lots of things with it. And we **use** it a lot, we really **need** it. We can **rely** on Nature to give us oxygen, and it's where we get our meat from and stuff. Some of Nature we **use** for jewellery, and they **take** medicine out of plants. Nature doesn't grow too much, it just grows **enough for us**. Some stuff there's maybe too much of it and so people **need to use it**, but other stuff there's only a little and they <u>over–use</u> it. For example, some of the

> animals they kill so now they are extinct, and they also over-fish, and now they‘re killing all the animals for their tusks. Nature becomes ruined when they become extinct, and then you can‘t just grow more. Some things in Nature you can‘t just fix, what‘s damaged is damaged. Rivers are polluted by, like, putting pesticides on the trees, and it rains, and it washes into the river and it kills the fish. Also, over-fishing. And sometimes they fish in the wrong places and they catch the mother and she‘s pregnant and then she can‘t lay her eggs and then they become less of those fishes. With people, Nature is much more noisy and more dirty than without people, so Nature needs to be protected….

As with the previous three worldview descriptions (epistemological, ontological, emotional), there were variations in the strength of students‘ status worldview descriptions, that is, the extent to which each student‘s status views were aligned with a particular descriptor overall (e.g., resource-oriented or conservationist). As such, some students held views that were strongly resource-oriented (e.g., Aamir), whilst other students held views that were resource-oriented but included a number of conservationist descriptions (Aaeesha). Likewise, some students held strongly conservationist views (e.g., Brian), whilst in other cases there were a number of resource-oriented descriptions were included in students‘ conservationist views (e.g., Dyllan). Therefore, in addition to classifying each case in terms of a bipolar worldview descriptor overall (i.e., resource-oriented, conservationist), the strength of each student‘s views was determined (e.g., resource-oriented or strongly resource-oriented). To this end, a resource-oriented—conservationist continuum was developed (Figure 4.11), which reflects a subtle variation amongst the strengths of students‘ bipolar status classifications.

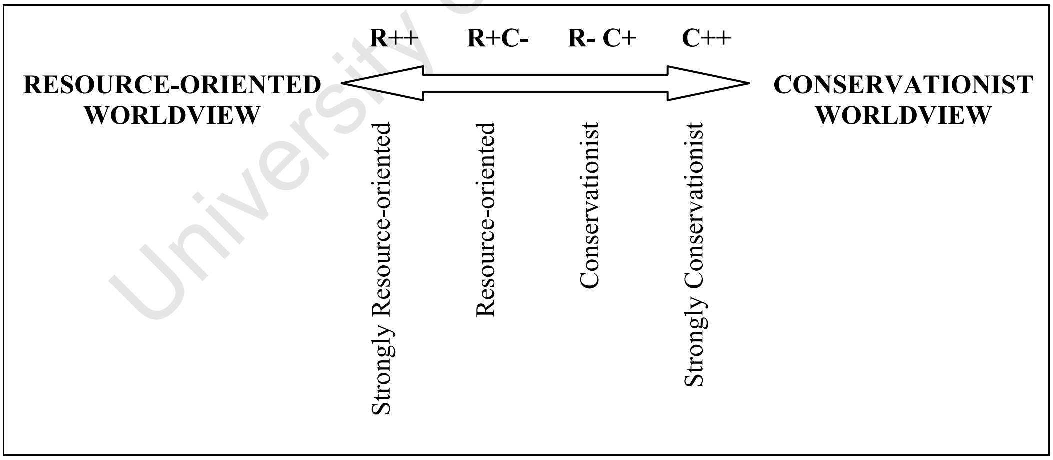


Figure 4.11: Continuum reflecting the relative strengths of the students‘ status worldview descriptions

At the one end of a continuum, strongly resource-oriented worldview descriptions (R++) included views that Nature is useful, we need it, and we can rely on Nature; Nature is not over-used; Nature is not ruined or destroyed; and Nature can be repaired/restored. In contrast, on the opposite end of a continuum, strongly conservationist worldview descriptions (C++) included views that Nature needs to be protected; Nature is over-used; it is ―ruined” and polluted; Nature is endangered and ―running out”; people kill things in Nature and species have become extinct;

man has an impact on Nature (negative/positive); and Nature cannot be repaired. Between these two poles were located views that were resource-oriented (R+C–), and conservationist (R–C+).

Each case was located at a position on a continuum, according to the relative weighting of the various resource-oriented and conservationist views that constituted the individual‘s status worldview description. For example, Reza held a strongly resource-oriented view (R++) of the natural world (Figure 4.12). Details of the remaining cases—located at each of the various positions on the Resource-oriented—Conservationist continuum—are provided in Appendix 4.7 (page 402).

Overall, the students described diverse status views of the natural world, and cases were positioned at all four locations on the resource-oriented–conservationist continuum (Table 4.14). Notably, the cases are relatively evenly spread across the four locations, although slightly more students (i.e., eight) described status views located on the resource-oriented end as opposed to views located on the conservationist end of the continuum (i.e., six).

Synopsis of Resource-oriented responses:	**R++**	**R+ C-**	**R- C+**	**C++**	**Synopsis of Conservationist responses:**
We use Nature We need Nature Nature is not running out We can‘t break Nature Nature will last forever Nature is not very dirty	**Strongly Resource-oriented**	**Resource-oriented**	**Conservationist**	**Strongly Conservationist**	There is pollution (litter) in Nature Only *Allah* can protect and repair Nature

Figure 4.12: Overview of the contents of Reza‘s status worldview descriptions

Table 4.14: Locations of the students‘ status worldview descriptions on the Resource-oriented—Conservationist continuum (see Appendix 4.7, page 402)

R++ Strongly Resource-oriented	**R+ C-** Resource-oriented	**R- C+** Conservationist	**C++** Strongly Conservationist
Aamir	Aaeesha	Dyllan	Brian
Reza	Dan	Gideon	Maya
Victoria	Raashid	Shanon	Shafia
Yamina	Samuel		

To recap, the students‘ status descriptions of the natural world included a range of views. The relative strengths of individuals‘ status descriptions were reflected by locating each case on a resource-oriented—conservationist continuum. Overall, the positions of the fourteen cases were more evenly spread along this continuum.

In summary, results of the worldview data focussing on four descriptions of the natural world (i.e., epistemological, ontological, emotional and status descriptions) show that the students articulated a range of responses relating to each of the four descriptions. Their views were diverse and typically included statements relating to both bipolar descriptors (e.g., epistemological views: descriptions included both Knowable and Unknowable statements). A series of four continua was developed in order to portray the varying strengths of the students‘ views pertaining to each of the four descriptions. The next section describes how a worldview profile was then generated for each case.

Worldview profiles

The students‘ worldviews were first analysed in terms of each of the four descriptions, as detailed in the previous section. A worldview profile was then constructed for each case, reflecting the particular combinations—and strengths (locations on the various continua)—of the four descriptors that were assigned to each student. For example, in the case of Maya, her worldview was classified as Knowable, Naturalistic, Positive, and strongly Conservationist (Figure 4.13). Each case profile synopsis comprised two parts, namely, a snapshot of the contents of the student‘s view of the natural world, and a diagrammatic representation of the alignment of the student‘s views with each of the four worldview descriptors.

Snapshot of worldview contents: From each of the students‘ worldview narrative, salient components of their worldviews were extracted, relating to each of the four worldview descriptions (i.e., epistemological, ontological, emotional, status descriptions). This content was listed under bulleted points on the left-hand side of the profile synopsis, in order to provide a snapshot of the contents of the student‘s worldview.

Diagrammatic representation of combination of worldview descriptors (and strengths): As described in the previous section, the students‘ views relating to each worldview description were located on a continuum, which reflected the relative strengths their views (e.g., epistemological description: knowable, or strongly knowable). The students‘ four continua were then combined in order to create a profile for each case. This is represented diagrammatically on the right-hand-side of the case profile.

Synopses of two case profiles are provided here as examples (Figure 4.13 and Figure 4.14), which demonstrate the uniqueness of each individual's worldview profile. Synopses for the remaining cases are presented in Appendix 4.8 (page 404).

MAYA – Jewish girl

- We can find out most things about Nature, although some parts aren't found; Nature changes but it is understandable and orderly; some things are unpredictable
- Nature was created by *Hashem* (God), but things are naturally there and Nature is doing its own thing
- Nature is beautiful, enjoyable and good; it can also be dangerous and destructive
- Man has a negative impact on Nature

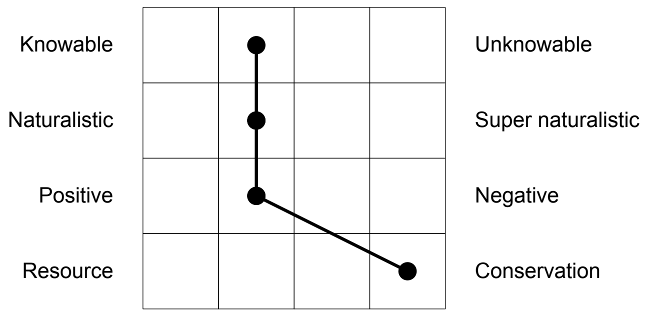


Figure 4.13: Synopsis of Maya's worldview profile

YAMINA – Muslim girl

- Nature is diverse, but it is orderly and understandable
- Everything has a purpose, although we might not know that the purpose is; God created Nature and He is in control of everything
- Nature is interesting and beautiful
- We can use Nature, and the resources on the land aren't ruined.

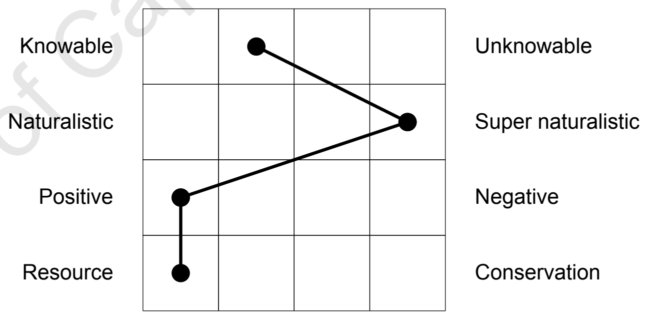


Figure 4.14: Synopsis of Yamina's worldview profile

A comparison of the fourteen worldview profiles compiled here reveals that in all cases each student's worldview profile was unique. Only one profile was repeated: Samuel and Aaeesha both held worldviews that were overall Knowable, Super-naturalistic, Positive and Resource-oriented (although the particular contents of these two students' views of Nature remained distinct from one another). There was great diversity, therefore, amongst the views of the natural world held by the fourteen students studied here.

Coherence within the students' views of the natural world

Results provided thus far indicate the richness and diversity of the students' views of the natural world. The students' worldview descriptions were analysed further in order to determine the extent to which their views of the natural world were internally coherent. To this end, Thagard's (2006) principle of system coherence was applied in evaluating how the various statements comprising a student's views of the natural world were coherent with the rest of the worldview ideas s/he articulated. Contradictory statements within a student's worldview responses were identified as system incoherence (Chapter 3, page 100). Furthermore, where a student's worldview statements contained a mixture of views (e.g., descriptions of Nature as both knowable and unknowable), these were identified as instances of system complexity (Chapter 3, page 100). In the majority of cases (i.e., in 12 of the total 14 cases), students' worldviews contained various instances of system complexity and system incoherence. Specifically, nine students' worldviews included instances of system complexity (i.e., Dan, Maya, Aaeesha, Raashid, Dyllan, Gideon, Samuel, Victoria, Shafia, Shanon), and six students' worldviews contained instances of system incoherence (i.e., Dan, Aaeesha, Reza, Raashid, Yamina, Brian). In three cases, students' worldviews revealed instances of both system complexity and system incoherence (i.e., Dan, Aaeesha, Raashid). Indeed, in only one case (i.e., Aamir) were no instances of system complexity or system incoherence identified. (page 201).

The various instances of worldview system complexity and worldview system incoherence were found predominantly within the students' epistemological and ontological worldview descriptions. Moreover, from the analysis of these various instances, a number of issues emerged. For example, *epistemological* descriptions included Knowable statements (e.g., some parts of Nature are known, understandable, studied, predictable) alongside Unknowable statements (e.g., some parts of Nature are unknown). *Ontological* descriptions included references to Naturalistic theories (e.g., Big Bang and evolution) and to physical causes/processes in Nature. These Naturalistic views were held alongside Super-naturalistic statements (e.g., beliefs concerning Creation and transcendental involvement in Nature). *Emotional* descriptions included statements that were Neutral (e.g., Nature is something we see every day) and Positive (e.g., Nature is not just there and we need to appreciate it more). *Status* descriptions included Conservationist statements (e.g., Nature is ruined) alongside Resource-oriented statements (e.g., Nature can repair itself).

Instances of system incoherence and system complexity are presented next, with respect to each of the four worldview descriptions (i.e., epistemological, ontological, emotional, status), and organised according to themes arising amongst the various issues listed above. Each theme is presented by means of a synopsis of each instance of system incoherence/complexity, and is supported by extracts from the students' original worldview statements.

Epistemological descriptions

Instances of system complexity and system incoherence found within the students' epistemological worldview descriptions were related to five themes, namely, Can we know things about Nature?, Can we predict what will happen in Nature?, What has been discovered/proven and what is unknown?, How much of Nature do we understand, and do we need to study it further?, and, How do we find out things about Nature?

Can we know things about Nature?

- Unknowable vs. Knowable

According to Gideon, people can know some things about Nature but it is largely unknowable. In the future, however, it might be possible for someone to find out everything about Nature (System incoherence).

> **You can't understand the whole thing**, but you can understand **bits of it**.
>
> I think that if there's some scientist out there who is out to find out everything about Nature and know…and it's happening now, then **it might be possible**. But I don't think that it will happen for a while.

- Complicated & undiscovered vs. Understandable

Aaeesha described Nature as confusing and difficult to understand, and therefore mysterious. Moreover, there is a lot in Nature that remains undiscovered. However, she also said that most of Nature is understandable (System complexity).

> …Some of Nature is **difficult to understand**, like, how the bodies of the animals function, and the natural metals, how metals can be liquids and solids. Some of Nature is **complicated** and **confusing**, like, how water can come from rocks in the Cango Caves, and how the fish have to lay their eggs out of their mouth.
>
> Sometimes when Nature changes we maybe **don't know why** it has changed, and then it becomes a **mystery**, if we **can't figure it out**. I think there's a lot of stuff that we **don't know** about Nature, like, some animals that **haven't been discovered yet**. There's probably a lot of stuff nobody's discovered yet and **there always will be more** that man can discover.
>
> We can **know** most things about Nature, like the way food chains work, and we can keep on **learning** things about Nature…Most of the stuff in Nature we **understand** how it functions, like cows, how they eat the grass. They don't really chew it. They just put it in their stomachs and then later they'll bring it up and they'll chew it, and then they'll just let it out!

- Confusing & mysterious vs. Understandable

According to Samuel, there is a lot about Nature that is not understood, and this is confusing and mysterious. However, Samuel also stated that people can learn about and understand most of Nature (System complexity).

> There's a lot that we **can't understand**, like why tornadoes happen, so Nature is definitely **mysterious**. It can be **complicated** how everything works and we'll **never**

> **be able to find out** the meaning for, like why does the tide in the ocean actually go like that, why is it bigger, high tide is here, low tide is there or whatever…It is quite **confusing** to figure out when something‘s going to happen, or why it happens.
>
> Some of it we **do understand**…
>
> [If [I] think about Nature, most of it we do know and can get to know**… it's mostly stuff [we] can understand**].

- Everything is linked vs. Unknown purpose

According to Raashid, people can never know why things were created. Yet everything has a purpose and is linked (e.g., food chain). Biologists find out about Nature (System incoherence).

> God created things for a specific reason and **we can never actually know** why it was created**. Everything has a purpose and everything links up**. **We learn how animals link up**, because how they eat, for example, the food chain. **Biologists** work with animals and **find out** what they eat. The bee, for example, plays a big part in Nature. Without the bee—butterflies also—there wouldn‘t be any pollination. When the bees pollinate they create nectar for the honey, and without their pollination, who knows, the trees and seeds might not be able to spread. And water, for example, what would animals do without it? They would be so thirsty. And without water there would be no sea life, no fish. Take the clown fish, for instance, where would it live if there was no anemone?

- Complicated, strange & unexplained vs. Orderly & predictable

Dyllan described the natural world as confusing but partly understandable, in that it is complicated and strange, and there are some things that cannot be explained. However, there is some order in Nature, and future events are predictable (System complexity).

> Nature is **complicated**. Volcanoes just erupt. Why do they erupt, if for five years it stays the same and then it just blows up all of a sudden? Why do hurricanes start? How do they start? Why do fires happen and just grow and grow, and cause havoc?
>
> There are things that happen in Nature that‘s quite **strange**, like the desert. How did all that sand get there? **It's not simple and ordinary**, like you see a whole place full of sand and it‘s quite **strange** to see. And when I look at a jellyfish, I just see this thing, and it looks quite **strange**, and all the animals look quite **strange** because they all play different parts in their lives. Every animal has a different role, like the bee gets honey from a flower and he puts it in the hive. A cow eats and then he gives us milk…
>
> And sometimes I **wonder**, with my dog, he just does this **weird stuff** and **there's no real answer**. Sometimes he just digs holes in the ground even if he has no bone. **I don't understand that**. And he‘s got an ear problem, so we keep cleaning out his ear and we take him to the doctor and then his ear is fine again, but afterwards his ear is funny again. It goes on like that forever, so it‘s **confusing** to me. **There is some stuff in Nature that we can't give an explanation for**.
>
> In Nature, **we can tell what's going to happen in the future**, like people say that in 2012 there‘ll be another eclipse where Venus will come over the sun. They say the next time that will happen is like in the thousands of years‘ time, so **there must be some order in Nature**. There is like **a cycle** in Nature. For example, the cows eat lots of grass, then their tummies get big then they can give us milk. Then we drink the milk to stay healthy so we can still feed them.

Can we predict what will happen in Nature?

- Predicting and preventing tornadoes

According to Gideon, people do not yet understand tornadoes and therefore cannot predict or prevent them. He expressed hope that it will one day be possible to prevent tornadoes, but was unsure if this could indeed be achieved. At present, according to Gideon, the only thing that is predictable in Nature is the growth of fruit/vegetables (System complexity).

> Nature is fascinating…and mysterious. If you have a lot of equipment and a team you can work out how [things happen]. But it‗s complicated. **We don't understand the tornado**. I‗d like to know how it starts. It is obviously being monitored by a satellite because of the pictures, but just the way it starts, I think is complicated. I mean, it could just start as a light breeze then become something huge in two seconds**. In the future I hope we will be able to prevent tornadoes** by sending something out to stop it, like maybe a really powerful vacuum cleaner!… It is absolute chaos when a tornado hits. But **you have to be able to predict it to be able to see it's coming**.
>
> **I *hope* we might be able to prevent tornadoes**, but that hope is like, well **we don't know, maybe they can, maybe they can't**.
>
> …**You have to understand something to be able to predict it**…
>
> Other stuff in Nature you **can't predict**…I guess **the only thing you can really predict is fruit growing**, vegetables growing. You can predict that…

- Predictable vs. Changeable & unpredictable

Samuel viewed Nature as somewhat predictable (e.g., seasons, blossom), although he also described the natural world as being changeable and unpredictable (e.g., daily weather) (System complexity).

> Nature **changes** all the time, like, **the seasons…and the weather can change**, from hot and rainy some days. My dad was having his 40th [birthday party] outdoors and we had to quickly go and hire a place because it was raining… **Anything can happen at any time**, like, tornadoes or earthquakes. So Nature is **not predictable**, ‗cos, like, the weather can **change**, one day it‗s hot, one day it‗s cold. We know, kind of, like, the seasons as being summer, here it‗s hot and winter it‗s going to be cold and it‗s going to rain in winter, and we know that spring there‗s going to be blossoms…**so it could be predictable, but otherwise it's not**.

- Unpredictable vs. Knowledge of the future

According to Raashid, one never knows what might happen in Nature (i.e., Nature is unpredictable). However, he also said that one has to be ―very clever" to know what will happen in future (i.e., it is possible to know/predict) (System complexity).

> You never know what can happen in Nature (i.e., **unpredictable**). You have to be **very clever** to tell what will happen in future.

- Changeable & unpredictable vs. Orderly, understandable & predictable

Maya described changes in Nature as unpredictable and confusing, but she also said that some changes are orderly, understandable and predictable (System complexity).

> Some things in Nature are **predictable**. My mom always says when you drive past the mountain, if the animals are down at the bottom it‘s going to rain, and then if they‘re higher up it‘s going to be hot, and usually when they‘re down it rains. But if there weren‘t satellites to tell you what the weather was then **it wouldn't be predictable**, for example, storms. The weather is the most frightening thing about Nature, and **it is confusing because it changes**. And in Nature, **things could change**, like seasons could change, and then the colours of things could change, like leaves, and fruit if they‘re ripe or not, or leaves if they‘re dying or not. Some things grow and things die and things stop and go. And like volcanoes, they sometimes erupt and then they stop for a long time and then they‘ll erupt again. So it can be **confusing**, because **you don't know when those things are going to happen**. But it is also **understandable** because **you can understand why it's changing**. For example, you can **understand** the leaf is dying, maybe because it‘s not getting enough water, and you can help it live again.

What has been discovered/proven and what is unknown?

- Other planets undiscovered vs. Proven

According to Raashid, current technology is not yet advanced enough to allow people to travel to another universe and discover find more planets, yet he also stated that there is already proof of the existence of other planets (System incoherence).

> At the moment our **technology's not to that level**, go to another universe and **find more** planets.
>
> …We have **proof** there are other worlds, other planets.

- Dinosaur bones/evidence vs. Mistakes/uncertain

Raashid further described evidence of dinosaurs‘ existence (e.g., bones) and how archaeologists can reconstruct parts of dinosaur skeletons (e.g., rib cage, spine). However, he expressed uncertainty regarding skin colour and the accuracy with which dinosaur skeletons have been reconstructed (System complexity).

> There‘s lots of evidence that dinosaurs did exist, bones and all. **I wonder how people know the colour** of the dinosaur? **Because they just found the skeletons, not the skin**. And **who knows**, when they were building the bones, they could have made a **mistake** and structured it **wrong**, so **maybe the dinosaurs don't really look like that.** Archaeologists dig up **bones** and they can see what links up. They more or less know the bones, like, what the rib cage and the spine looks like. But maybe a bone can fit in two places and they **put it in the wrong place**.

How much of nature do we understand, and do we need to study it further?

- Complicated & don‘t understand, would like to know vs. No need to study it

According to Gideon, the natural world is complicated and there are things we don‘t understand and would like to know. Yet there is no need to study Nature (System incoherence).

> …But it‘s **complicated**. We **don't understand** the tornado. **I'd like to know** how it starts. It is obviously being monitored by a satellite because of the pictures, but just the way it starts, I think is **complicated**. I mean, it could just start as a light breeze then become something huge in two seconds…
>
> …But **how** was ice discovered? **How** was it found? *(i.e., Don't know.)* I mean, now we have freezers that does it in ten [or] twenty minutes, but the question is, if you were to take

the camera and watch it happen, **what would you see**? And then **we don't understand** it. So it's maybe more **complicated** than we thought.

We could learn more about Nature, but **I don't think it's something that has to be studied**.

- Understandable vs. Complicated and no need to study

According to Victoria, the natural world is understandable, things happen for a reason, and people can find out things about it—by means of science. However, she went on to describe Nature as confusing, as some parts are complicated. Furthermore, Victoria held the view that mysteries in Nature should remain unsolved, and should not be researched or studied, in order that people continue to enjoy simply being in Nature (System complexity).

…**most of Nature is understandable** because of the **system**, as **things do things in certain ways**. Flowers bloom **in a certain way**. You can see it unraveling slowly, slowly, until it's a beautiful flower, and **you can understand it**. Nature is a very interesting thing and **we can find things out** by doing **research and studies**…Specific people, mostly **scientists**, do this kind of work…

Nature is **complicated** in some ways, the way some things work to get how they are. Like a seed, it doesn't just go, just pop in the ground, you water it and then ―Wow!" You have to look after it and it grows in certain stages and steps. You can sometimes get **confused** by Nature because it is **complicated** and because it **changes** in so many ways.

…But **we don't really need to study Nature or to learn more about it**, otherwise it might just take away the lust to be in Nature. It's nice to have **some mysteries unsolved just to keep it fascinating**. Nature is **mysterious**, like, how does the ice stay ice even though the sun comes down on it?...It is **mysterious** even though **we are used to it**.

- Know it all vs. Study/learn more

According to Brian, people already know much about Nature, and little new knowledge has been added. However, he also said that yet there is more to Nature (e.g., undiscovered planets, new viruses/sicknesses, new animal species), and therefore Nature should be studied in order to learn more about it (e.g., find a new planet to live on) (System incoherence).

We can **understand** a lot about Earth and about every animal. **There's nothing not to understand about Nature**. We **already know** what is going on and **what will happen**. For example, **we can say** what the weather will be like from the satellites. I've seen a lot of Nature so I **can't get confused** between which is which animal. And we **know** the name. We see so much of one thing that **we already know so much about it**. And we **don't have to be confused** about Nature because other people can **explain** it to us. So Nature is also **not mysterious** because **most of it we already know**. **We haven't found out that many new things about Nature**, and finding out new things about Nature would make it seem mysterious.

…We might see **new sorts of animals** in Nature and **find out new things** about it, then Nature is fascinating…In Nature **we see lots of everything** like trees, flowers, and eggs, and animals like birds, so it is ordinary…And you **know what's going to happen** in Nature, like, when there will be a volcano that will erupt. But **I think there'd be more stuff to Nature**, like, the wind that we can't see, and other planets that we haven't found yet. Or **we might just find a new virus or sickness, and new animals**.

> We **know** there will be global warming because of what we‘re doing, adding gas to the atmosphere with pollution, so it becomes thicker and it gets hotter. The global warming might just burn down everything on Earth so I don‘t think there will be any Nature on this planet…We would need to find a new planet to live on, **so I think we should study Nature and learn more and know more**.

- Unknowable vs. Protect & learn

Raashid stated that people cannot know about things about Nature. However, he also described a need to learn about Nature so that it can be protected—and if Nature is protected, then it will be possible to learn things about it. Biologists were identified as the people who study Nature and who can teach others how to protect it (System incoherence).

> There is **lots of stuff we must still understand and discover**. It will take very long studies, but **we can’t learn how everything works** because there could be stuff you **haven’t discovered yet**. We could make a **mistake** in Nature. We can **never know** what it really is. And we can get **confused**. Nature is very **complicated**.
>
> **We should learn about Nature so we know how to protect it, and if we don’t protect it we won’t be able to learn about it**. But there *are* **people who already know** how to protect it so they can teach us. So not all of us should be studying it. **Biologists** study Nature.

How do we find out things about Nature?

- Knowing about Nature through direct experience vs. Not knowing

According to Yamina, anybody can observe and know things about the natural world. However, she also described a lack of knowledge about natural events that people experience physically, such as storms, rain and volcanoes (System incoherence).

> To find out things we get **research**. **Anybody just sees and finds out**.
>
> …Storms are things we **can’t find out** about in Nature. And we can‘t predict when it will rain. Sometimes it just starts raining **without us knowing**. And if the volcano has been sleeping for a long time and it suddenly erupts, that isn‘t ordinary. But everything has it‘s purpose in Nature. Maybe it just happened to be there was a storm or something in Nature, but it could be to water the plants or to give the dams more water. ***We don’t normally know*** what the purpose is. But God is above all, so He controls everything in Nature. Maybe God sent the storm but **you don’t know why**…

- Science vs. Anybody finds out

Further to the above instance of system incoherence, Yamina stated that she learned about Nature in Natural Science, yet she also stated that Nature is not exclusively the domain of scientists (i.e., anybody can go and find out things about it) (System incoherence).

> The things I **know** about Nature I learnt at school in **Natural Science**. To find out things we get **research**. Anybody just sees and **finds out**.

- Scientists study & tell us vs. I don‘t know their answers or methods of knowing

Brian described how scientists have discovered Nature and studied it, and that they have been informing us about it. However, he also expressed uncertainty about how exactly scientists learn things. Moreover, whilst not knowing scientists‘ answer, he would rather believe in God (System incoherence).

> **Scientists have discovered Nature and studied it** and they‘ve been telling us, **so that's how we know things**, although **I don't know exactly how they find out things**. They do have technology, like to find out how big a dinosaur was, they just put it in some scanner and that says how old. **Scientists always have an explanation or an answer to why**, like, why did we have animals, and why there were cave men and things like that. And **they always try to prove people wrong**. But some people believe in God, and they tell stories about God that we believe more than we believe what the scientists tell us. Maybe because when scientists were smaller their parents also didn‘t believe in God so they couldn‘t go to church and learn about God so the **scientists** have to find other reasons to **explain** things. **I don't know what the scientists' answers are, but I'd rather believe in God**.

Ontological descriptions

Instances of system complexity and system incoherence within the students‘ ontological worldview descriptions were related to the following four themes: Is Nature a holy and spiritual place?, How was Earth formed?, What are the causes and purposes of natural events/phenomena?, and, Do we believe scientists or God? Instances of system complexity/incoherence relating to the last three themes (i.e., How was Earth formed?, What are the causes and purposes of natural events/phenomena?, and, Do we believe scientists or God?) included responses relating to interactions between different explanations offered by science as opposed to students‘ personal worldviews (including their religious beliefs). As such, the students‘ responses relating to these three themes contained evidence of border-crossing issues, including compromise views and explicit conflicts between science and religion.

Is Nature a holy and spiritual place?

- Spiritual vs. Not holy, just there

Samuel described how Nature could provide a spiritual experience for him in his enjoyment of being outdoors. Yet he also said that Nature is just there and that it is not holy (System complexity).

> Nature can be **spiritual**. It‘s more spiritual than things that we‘ve built, definitely, because it‘s just like a scene that closes up on you and it makes it **spiritual**. Like, we can just lie on the grass looking at the clouds, and like the wind just blowing up in our faces….
>
> But **I don't think Nature is holy**, because no religions in the world believe that Nature‘s holy, except for, maybe, like Indians or something, cows are holy. Except I don‘t think they believe in it any more. I think that they stopped.
>
> Nature is **just there**, like, we can go there once or twice and just **watch** animals, or plants, or desert areas, or whatever. We know it‘s there, because we can **touch** the flowers and the rain, plants and animals… **We can go anytime** to a beach and **there'll be Nature there**…

How was Earth formed?

- Created by God or by Nature

According to Brian, God created everything. Yet the natural world was made by Nature and it is not holy or spiritual (System incoherence).

> **The natural world was made by Nature** so it is anything that has not been man-made. Humans are part of Nature, except for their clothes, because that's too technical. We are told *[vs. I believe]* **that God created everything** in Nature. But **for me Nature is not holy or spiritual**. It is **not holy** because we don't pray to Nature because they're not actually listening. We pray in church. And **Nature is not spiritual**, like, —Hmmmm" and things like that and we think that trees will come alive. **There's no spirit in the trees**. They're just there. *[Note: the phrase in italics was inserted by the researcher.]*

- Creation vs. Big Bang & evolution

According to Victoria, God created the Earth, and He created the Big Bang. The Big Bang then started the process of evolution (System complexity). Despite her super-naturalistic view of the natural world, however, Victoria expressed doubt in her religious belief regarding creation. She therefore drew upon both super-naturalistic (creation) and naturalistic (Big Bang theory, evolution theory) explanations in reconciling conflicting explanations about how the Earth began (a compromise view).

> I think Nature is holy, because **God created the Earth**, although we don't know for sure it was created. **I believe that God created the Big Bang** and then started **evolution**.

- Physical processes vs. Creation

Aaeesha's view of Nature included statements that many years ago, there was continental drift and the Big Bang. However, this naturalistic view was in contrast to her statement that God created Nature (System incoherence).

> Other changes in Nature are, like, the **Big Bang**. All the continents were first one, but so the **Big Bang came and it split them into seven continents**, and they are still moving.
>
> In fact, **Nature is about everything that God created**.

Samuel stated that physical processes are involved in the changes that occur in the natural world (e.g., the formation of mountains), but that someone powerful (e.g., God) must have been involved in the initial creation of Nature (a compromise view) (System complexity).

> No religion thinks that Nature created itself or anything like that. **Someone has to put a mountain there**, and **then the mountain turns to sand**, and every single year the mountain gets bigger, and eventually two mountains hit and millions of sand just comes down and goes into the ocean…I don't know. Just **someone had to make it…to start with**. I think **God created it** ‗cos only **someone** so powerful can make something so big and powerful.
>
> …How did [Nature] get that beautiful and **who** made it so beautiful? Also it is fascinating how we don't have to build anything onto this world. **It's just already done for us**.

Shanon also stated that God created the world, but that Nature is formed by physical processes over time (System complexity).

> …I think **God must have created the world…**
>
> Nature is **formed by** lots of different things, like a mountain is formed by lots of different

> **minerals** inside, and beach sand is lots of different shells… when times change mountains are **formed by time**…

Further statements by Shanon revealed an explicit conflict between her religious views and science, regarding the origin of the Earth and her inability to choose between the two opposing explanations (a compromise view).

> Either **God** made Nature or something else made it, something **scientific**…God created the world in seven days, and, the world was built up by lots of different minerals forming together. And **there's so many different theories that you don't know which one to choose**...Because you know that you kind of **believe in both** in a way. Or you want to…**You can't really choose between them**…

Shafia also articulated explicit conflict between her religious beliefs and scientists‘ explanations of how Earth was formed. However, she considered that perhaps both explanations could be correct (System complexity).

> I believe in my religion very strongly. Before we started on this Earth, everything here was Nature. **The scientists say that there was a Big Bang, but in our religion we say that Allah made the Earth**, the stars and everything. But if it was the Big Bang, how did the Earth, the planets get there in the first place? There could have been a Big Bang, but if there was a Big Bang there must have been something, the person who made the thing before the Big Bang. **The scientists don't know what to say about that**. That‘s why we say that Allah created it…**The scientists could be right *and* we could be right**.

What are the causes and purposes of natural events/phenomena?

- Physical processes/purposes/causes vs. Transcendental involvement

Shanon described how, for example, tsunamis are caused by physical processes, but that natural disasters occur as a transcendental response to people‘s actions (System complexity).

> [Re: tsunami just doing its job] Because **it is a part of Nature, and it is going to happen** when, like, the waves form themselves into one big tidal wave, it‘s, like, where‘s it supposed to go? It‘s not going to put itself back into the sea, **it has to spread out somewhere**, so…
>
> Religious people, **priests and rabbis**, say that when tsunamis and droughts happen **people have done bad**, and when there is nice **rain people have done good**, although **I'm not sure I believe all those things**. I think that everything has a reason, although you can‘t always figure it out. Tsunamis and volcanoes happen for a **purpose**, linking them to **spirituality**.

Notably, however, Shanon expressed some uncertainty about religious teachings (—I‘m not sure I believe all those things"). Moreover, Shanon articulated an explicit conflict between science and religion. She stated that if ultimately faced with a choice between science and religion, she would hold onto her religious beliefs more strongly—especially in regard to the issue of creation.

> ...**Even though scientific things and religion clash, I think God must have created the world** otherwise it wouldn‘t have been so beautiful, and He must be somewhere in it.

Regarding natural disasters, Aaeesha said that that they occur because the Earth is changing.

Yet she also described natural disasters as a form of punishment from God (System incoherence) (Aaeesha).

> **Natural disasters** happen because the **Earth is changing**.
>
> …In our Islamic Studies, we learn that **God sent down natural disasters** in Nature **because the people didn't follow the prophets**.

Samuel described physical purposes for natural events (e.g., rainfall, drought), but he also said that the purpose of some natural phenomena is either uncertain or involves some degree of transcendental intervention (System Complexity).

> Things happen for a **purpose** in Nature, like we need water so it gives us rain, and you can have sunshine and all of that.
>
> …If there‘s a drought, it‘s because we‘ve destroyed the ozone layer and so now it has to become cooler over time. Well, it‘s not like all of a sudden if we fix the ozone layer. The heat‘s still going to go slowly but surely out of the earth and into space… but not just straight away. But once the ozone layer‘s fixed it‘s going to become cooler…because not all the heat‘s just coming in from the sun.
>
> It is quite confusing to figure out when something‘s going to happen, or why it happens. Like, **who's** causing it. Anything can happen at any time, like tornadoes or earthquakes.
>
> …We‘ll never be able to find out the **meaning**[12] for, like, why does the tide in the ocean actually go like that, why is it bigger, high tide is here, low tide is there or whatever…

Do we believe scientists or God?

- Naturalistic descriptions vs. Believing God

Dyllan articulated explicit conflict between what is presented to him in church and what his science teacher tells him regarding the end of the world. Due to his mistrust in scientists, Dyllan chose to hold onto his religious teachings beliefs rather than onto what he had been told during school science lessons (System complexity).

> I think that there was no beginning to Nature, and it will always be there, like, the planets. We can die but the planets will still be alive. The earth can go into a hole but then there‘s still another five hundred million planets still there**. Our teacher says in science** that **scientists say** the sun is going to blow up or it is going to fall into itself, or the Earth is going through the same thing, but in one billion years. That‘s quite a long time. But **I don't trust what they tell us**, because **when I go to church**, they sing a hymn where the last line says, ―world without end" and it goes ―Amen". So **I think if God says there will be no end, I think that's right. I don't believe the scientists**. They are not super-humans. They also make mistakes, so **maybe they're wrong** about the world ending.

- Scientists tell us everything vs. I don‘t believe scientists

Brian also articulated explicit conflict between explanations (―stories") provided by scientists and the stories he had been told by religious people. He managed this conflict by choosing to believe in God (System incoherence).

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[12] Samuel‘s reference to ‗meaning‘ implies a question relating to super-naturalistic explanations. In contrast, a reference to ‗cause‘ would be more likely to elicit naturalistic explanations.

> **Scientists always have an explanation or an answer** to why, like, why did we have animals, and why there were cavemen and things like that. And they always try to prove people wrong. But **some people believe in God, and they tell stories about God that we believe more than we believe what the scientists tell us**. Maybe because when scientists were smaller their parents also didn‘t believe in God so they couldn‘t go to church and learn about God so the scientists have to find other reasons to explain things. **I don't know what the scientists' answers are, but I'd rather believe in God**.

Gideon‘s belief in creation was accompanied by some uncertainty, as he expressed doubt in what is written in his religious scriptures. This doubt stemmed from a mismatch between what these religious texts and the physical evidence that has/not been found (System complexity).

> Nature is just there, it is. But the question is, **did we do something to create Nature, or was it just there when we were created?** I believe that **He created the world**, but I think that Nature‘s something that controls itself. **I do believe in God, but I don't really see the work of God in Nature**. Nature isn‘t holy in a biblical way because it doesn‘t really have a culture. There are many things in the Jewish Torah that I seem to not understand about Nature. **Because it says in the Torah**, there were mountains that **have been searched for and searched for many years and not been found**. So the question is, did they just disappear? **Is what's in the Torah true?** That‘s another question!
>
> **What** *[vs. Who?]* is Nature created by? [Nature‘s created by God but then Nature carries on and does its own thing…] **I think it's possible—I'm not saying that I totally believe this—it's possible, that Nature's created by God**. But I think that once Nature‘s created, if it‘s by God or not, it‘s now controlled by itself. *[Note: the phrase in italics was inserted by the researcher.]*

The second extract for Gideon indicates a compromise view, in regard to Nature possibly having been created, but now being self-determined.

Epistemological and Ontological descriptions

Instances of system complexity and system incoherence were identified between students‘ epistemological and ontological worldview descriptions. These instances were grouped according to two themes, namely, Who can know about Nature: People or God?, and, Why do things happen in Nature?

Who can know about Nature: People or God?

According to Reza, the natural world is complicated and much searching is required in order to learn more about it. Nonetheless, Nature needs to be studied, although God controls what happens in Nature and only He knows what will happen in the future (System incoherence).

Nature is complicated and difficult to understand:

> It is **complicated** because in the whole world there‘s a lot of things that is Nature. If you‘re very interested you can search about it. But **it will take a very long time to understand it**. And we can‘t put things from our minds into it. You can‘t just get it now, just go and write all it down…you go to search and there you see it.
>
> **You have to search the whole world and so it will take millions of years**. You have to do **a hard job**, you have to go walk, to have to work like a donkey! It is almost like you

> will never know unless a person tells his student, ―This is what I found and this all I searched about; if I die one day then you must search on and when you find things show it to the world".

Yet Nature needs to be studied so that we can know more about it:

> **Nature must be studied**, because if we don't know we can't talk about it so we won't have knowledge about that….

However, God controls what happens in Nature:

> **Without God things can't happen in Nature**. He can take the flood away or if God wants Nature destroyed it can be destroyed.
>
> **If God wants**, the ice will break, but sometimes **if God doesn't want**, the ice will stay like that…**God controls everything**.
>
> In Nature, if you damage the mountain it can't be repaired **until God wants** it to be repaired. We can protect Nature by not littering, but otherwise **only Allah can protect** Nature.

Moreover, only God knows what will happen in the future:

> **Only God will know what will happen in the future**…Like, you can't say a person's going to die tomorrow…A person can't [predict Nature] but the animal can: You can't say she will die in two days from her cancer...**if God doesn't want it to happen**. There was a man in hospital taking his last breath…the doctor walked away…the signal was going straight…his heart stopping…but then it was going up, up, and up… **it was God**, God wants him not to die…and he lived…

Why do things happen in nature?

- Need to know vs. Unknown purpose

Samuel stated that it is important to know why[13] things happen in Nature, although there are some natural phenomena that remain mysterious (System complexity).

> **There's no point in living in a world but we don't know**, for example, why does grass grow, why do we need water, why do animals eat other animals.
>
> It can be complicated how everything works and **we'll never be able to find out** the meaning for, like, why does the tide in the ocean actually go like that, why is it bigger, high tide is here, low tide is there or whatever…It is quite **confusing** to figure out when something's going to happen, or **why** it happens. Like, **who's** causing it. Anything can happen at any time, like, tornadoes or earthquakes.
>
> **I don't see a purpose** to earthquakes, because it's like the bottom of the earth is like this [two plates leaning up against each other]…[and it just gave in…] so that's an earthquake that people just fall in.

[13] Samuel's use of words such as ―why" and ―purpose" (as opposed to ―how") signaled that these issues were not merely epistemological (i.e., knowable or unknowable), but also ontological (i.e., naturalistic or super-naturalistic). On the one hand, questions of ‗how' ask about the reasons for things happening, which presupposes naturalistic explanations. On the other hand, questions of ‗why' signal a search for the purpose of events, and therefore might invite super-naturalistic explanations. Furthermore, explanations, albeit naturalistic or super-naturalistic, may or may not be known (i.e., epistemological).

… There‘s a lot that **we can’t understand**, like **why** tornadoes happen…

Emotional descriptions

There were fewer instances of system complexity within the students‘ emotional worldview descriptions than within their epistemological and ontological descriptions. Furthermore, these instances were related to a single theme, that is, Is Nature just an ‗everyday‘ part of life?

Is Nature just an ‚everyday' part of life?

- Appreciation and everyday Nature

Samuel described how Nature was something he saw everyday and therefore he did not stop and appreciate its beauty. However, he also pointed out that people spend too much time indoors with modern technological devices when they should rather be outside appreciating Nature (System complexity).

> I use Nature **every** single **day** when I go outside and I play sport on the grass and run around and play in my garden, but sometimes **I don't think** about how Nature made it so we could play on it and have fun. Like, **every single day I don't always stop and think** that it‘s so beautiful. My mom always says, ―Look over there, look over there, there‘s this…!" and I‘ve seen that a million times!

> I think in our modern time and age that we use Nature too little. **We spend so much time with technology and on the computer, and watching tv**. People go Ten-pin bowling and LaserQuest and watch movies every weekend. **We should rather be outside playing and appreciate what Nature has to offer**. Twice a year we visit my granny in Jo‘burg, and she lives in this huge flat that‘s got this massive garden and a swimming pool, so I just **spend time there**.

- Everyday vs. Go to Nature

According to Dan, the natural world is an everyday part of life and it is everywhere. However, Dan also said that Nature is not ordinary and it is not just something that one sees every day. One therefore has to go *to* Nature in order to experience it (System complexity).

> **Nature is an everyday part of life**, and sometimes when I‘m into my schoolwork I don‘t think about it much… **Nature is not ordinary because it's not just something that you'd see everyday**. You see different things every day and it‘s not just the same. If you don‘t see it everyday, you could see it on TV, you could go to a forest, you could go to a game reserve. You‘d **go to Nature**. Nature doesn‘t always come to you. And you can‘t, like, just walk down the street and just think Nature‘s going to be just down the road from me, ‗cos it‘s not. **It is not just there**.

> Oh, **it's not ordinary**. Nature‘s a beautiful thing. It‘s, like, really cool in a way. And **it's not just there**, like I said in the story, somebody must have planted it or something must have given seeds in it. And it‘s sort of linked up with, like, you won‘t just walk out your house and see Nature. **It's not just in front of you. You have to go to Nature. And it's not ordinary**.

Status descriptions

There was one instance of system complexity within a student‘s status worldview description, concerning whether Nature is ruined or can be repaired.

Is Nature ruined or repairable?

- Nature repairs itself vs. Ruined

Victoria said that Nature cannot be over-used because it cleanses itself and it re-grows. However, she also described how people are ruining Nature (e.g., deforestation in the Amazon region) and that such areas will not re-grow (System complexity).

> We can depend on [Nature] as **it will not vanish or float away**. Nature is **not over-used** because we have to use it. Imagine you walk past a blade of grass and this [sign] says, ―Do not use this. It‘s been over-used!" Anyway, **Nature can repair itself**. It is pure, like a fresh waterfall, but when somebody puts juice in it, the water will still come down and it will wash away the juice and then **it cleanses itself**. Nature **cannot be over-used** because **you can't over-use something that can't really expire**. Like, we may cut down a tree today, but you can plant another tree in its place. I think that‘s why most trees produce seeds, to **repair**, to **keep on growing**. You **can't destroy Nature itself**, because as many plants as you cut down, grass you cut off, there will still be the Earth, and the Earth is Nature …
>
> **Humanity might die out** if we don‘t take action and stop different pollution, such as air pollution, fumes from cars, the hole in the ozone layer that‘s growing bigger, and the amount of rubbish we throw away…Also, in the Amazon, the trees they cut down **don't really grow back**. They plant them again but we just push Nature out of the way to make space for our uses. That is ruining Nature.

In summary, a number of instances of system complexity and system incoherence were identified within most of the students‘ worldviews. That is, students‘ worldview statements typically contained a mixture of views that were aligned with opposing bipolar descriptors (e.g., knowable and unknowable), and/or their worldview descriptions contained contradictory statements. Overall, therefore, the students‘ views of the natural world were not internally coherent.

In conclusion, rich data were collected regarding fourteen students‘ views of the natural world. In general, the students defined Nature as being distinct from people and/or human activity. The students‘ views pertaining to each of the four worldview descriptions, specifically, revealed their worldviews are diverse and complex. Furthermore, their views of the natural world are not always internally coherent.

In the next section, results are presented concerning the analysis of coherence between and within the students‘ views of Nature and their views of NOS.

Part 3: Coherence

It is difficult to determine the coherence of individuals' views of the natural world and their NOS views by simply comparing the two. For example, little can be gleaned by comparing Dyllan's worldview profile (Figure 4.15) and his NOS profile (Figure 4.16) except perhaps concerning his apparent mistrust in scientists. Accordingly, a structured and systematic approach was required in order to conduct detailed analyses of coherence of the students' views pertaining to each of the four worldview descriptions and each of the five aspects of NOS. Such analyses were conducted by means of employing various principles of explanatory coherence (Chapter 3, page 97). Figure 4.17 presents a diagrammatic overview of the data that were collected and analysed concerning the coherence of the students' views.

DYLLAN – Views of the natural world

- There are things in Nature that I don't know and which are confusing, but once you've learnt about it we can understand parts of it—that's why we have science
- Nature has no beginning or end—I don't trust what scientists tell us as they make mistakes—I rather believe God
- Nature is fascinating, but it is also powerful and dangerous
- We need Nature for everyday life, but it cannot be repaired so it should be used sustainably

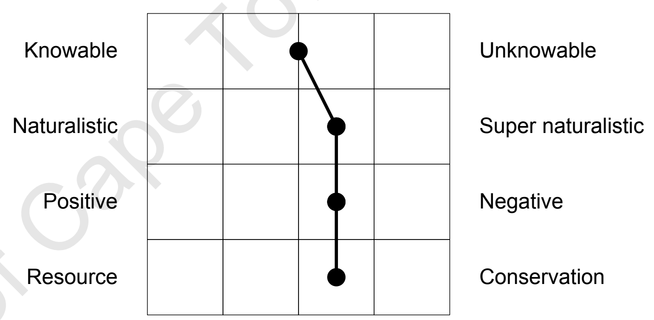


Figure 4.15: Synopsis of Dyllan's worldview profile

DYLLAN – Views of NOS

- With the help of new technology, scientists can change what they say—maybe they find they were wrong
- If scientists disagree it's because of insufficient facts or new technology, but it's not okay for them to disagree
- Scientists do chemical tests in their lab and they use technology;
- They don't have all the evidence about dinosaurs so they might be using their imaginations and fooling us;
- They take pictures of space but they don't really study space, and they might be incorrect or tricking us;
- I don't believe what scientists tell us; I also don't believe some things that my Dad says.

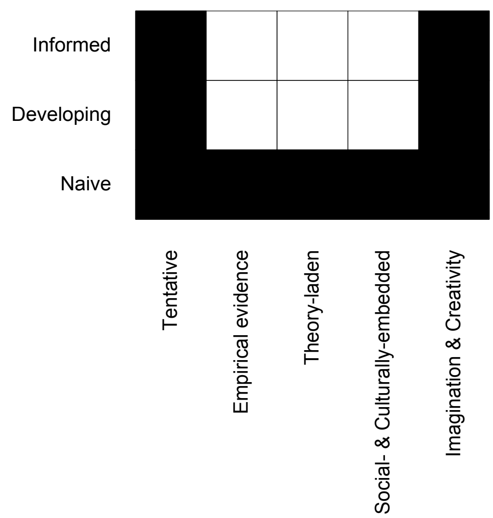
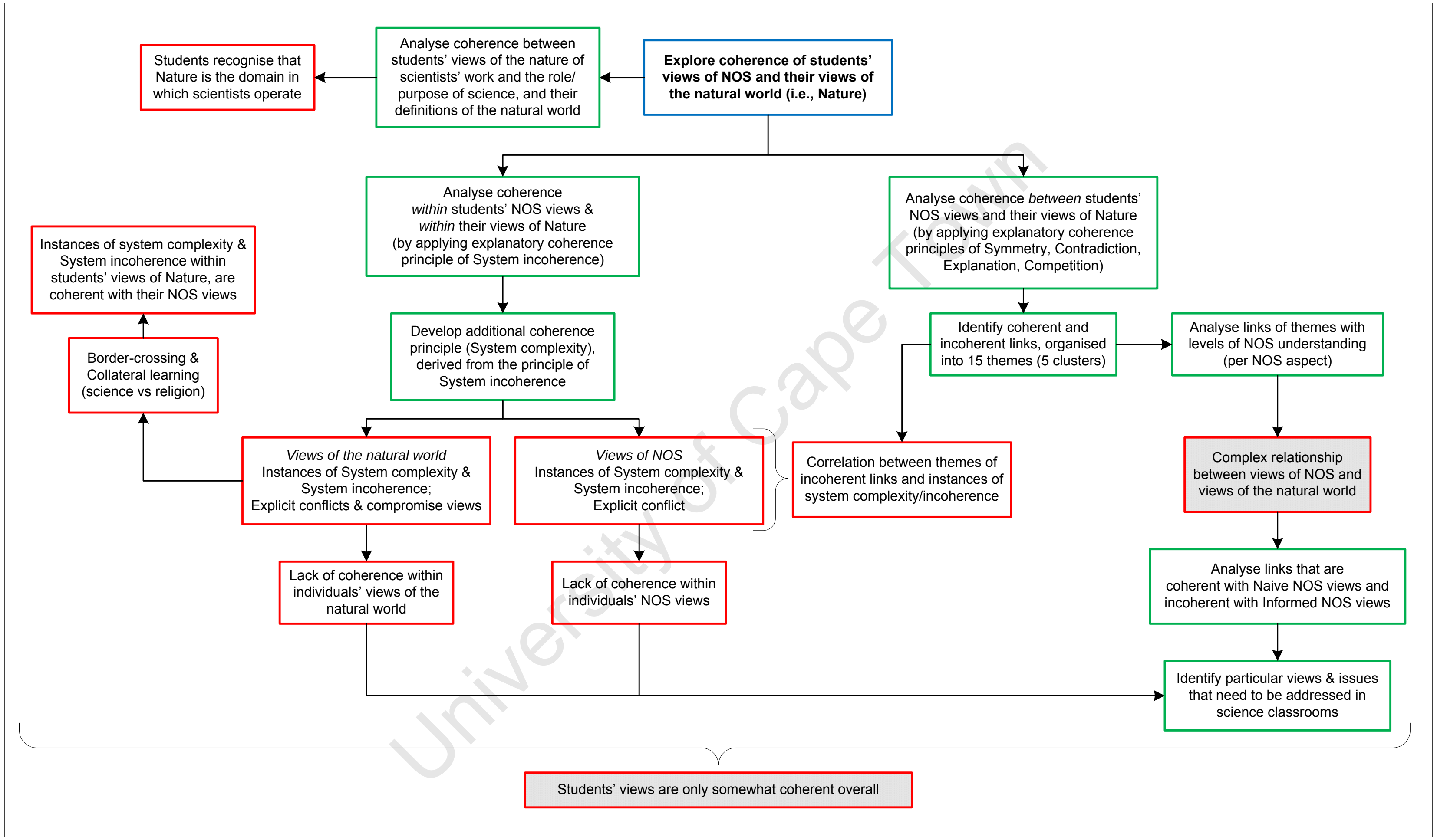


Figure 4.16: Synopsis of Dyllan's NOS profile



KEY: Blocks outlined in blue indicate data that were collected, blocks outlined in green indicate analyses that were conducted, and blocks outlined in red indicate results of the various analyses; Blocks shaded in *grey* indicate overall conclusions regarding coherence within and between the students' views of NOS and of Nature.

Figure 4.17: Diagrammatic overview of the data analyses of coherence within and between the students' views of NOS and their views of Nature

Analyses of coherence comprised three components, namely, (1) analysis of coherence *within* the students' views of NOS and *within* their views of the natural world, (2) analysis of coherence *between* students' views of each domain (i.e., coherence between students' NOS views and their views of Nature), and (3) determining the *overall* coherence of the students' views (Chapter 3, page 97). Results pertaining to the first have already been presented in detail, in describing instances of system complexity, system incoherence and explicit conflicts within the students' views of NOS (page 130) and within the students' views of the natural world (page 162). Consequently, the current section (i.e., Part 3: Coherence) focuses on the results of the second and third components of the coherence analyses. To begin with, the results concerning coherence *between* the students' views of NOS and their views of Nature are presented. This is followed by the results concerning the *overall* coherence of the students' views. However, in order to describe the results of the third component of the coherence analysis (i.e., overall coherence), there is a need to briefly re-visit the results pertaining to the first component (i.e., coherence within) and the second component (i.e., coherence between) of the coherence analysis.

What follows next, therefore, are the results concerning the coherence *between* the students' views of NOS and their views of the natural world. This involves a description of coherence between students' definitions of Nature and their descriptions of the work that scientists do. The results then focus on the analysis of coherent and incoherent links that were identified between the students' views of NOS and their views of Nature (described in terms of clustered themes). This is followed by a description of the themes of links that were identified in regard to particular levels of NOS understanding, as well as the results from further in-depth analyses of the links between particular worldview descriptors and levels of NOS understanding for each NOS aspect (and specific issues arising from these links). The results then focus on coherence between particular students' NOS views and instances of system complexity/incoherence within their views of the natural world (relating to border-crossing and religion-science conflicts). Having described these results concerning the coherence *between* students' views of NOS and their views of Nature, results are then presented of analyses concerning the *overall* coherence of the students' views.

Coherence between students' definitions of Nature and their views of the work of scientists

In the present study, it was found that the students' definitions of Nature and their views of the methods and aims of science were coherent with one another. That is, students described the natural world as being found both on Earth and beyond. Living things (e.g., plants and animals) and weather-related phenomena (e.g., natural disasters, such as floods and tornadoes) are part of Nature, but people and technology are separate from the natural world (Chapter 4, page 138). Furthermore, students recognised that, in order to find out more about Nature and to answer people‗s questions about the natural world, scientists study things such as plants and animals, the weather, and outer space) (Chapter 4, page 106). Amongst other things, scientists observe things in Nature by visiting particular locations and environments, and searching for evidence (e.g., looking at rocks and mountains, digging up dinosaur bones, taking samples of plant species, discovering sea creatures in submersible crafts, studying the solar system in spacecraft) (Chapter 4, page 106). Establishing links between the natural world and Natural Science therefore seemed unproblematic for the students.

What follows next are the results of the coherence analyses pertaining to the five specific aspects of NOS (i.e., tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative/creative).

Coherence between views of NOS and views of Nature: Coherent and incoherent links

Four principles of explanatory coherence (i.e., symmetry, contradiction, explanation, competition) were applied in analysing links between the students‗ worldview statements and NOS statements. In total, 197 links were established, by following the procedure described in Chapter 3 (page 97). These 197 links were reduced by identifying 15 themes amongst the contents of the various links, and then clustering these themes into five broader categories. The first three clusters of themes were concerned with knowing and finding out about the natural world and how certain or uncertain our knowledge is. The fourth cluster contained themes of links relating to differences between scientific explanations and religious beliefs, while the fifth cluster of themes included links relating to interactions with knowledge and with Nature (Table 4.15).

The majority of links were organised into the first three clusters concerning *Knowing and finding out* (63 links), *Sure knowledge* (49 links), and *Unsure knowledge* (52 links) (Table 4.16). By comparison, only 15 links were related to *Choosing an explanatory framework* and 18 links concerned *Interactions/transactions*. This result is perhaps not surprising considering that this study focussed on the students‗ epistemological views of science (NOS) as well as, amongst others, their epistemological descriptions of the natural world. Furthermore, the themes with the most links included *Find out and learn* (37 links) and *Unknown* (30 links), whilst the themes with the least links included *Emotional response* (2 links) and *Technology*

(2 links) (Table 4.16). This finding was an early indicator of which worldview descriptions were most useful in providing insights into the interplay between the students‘ views of the natural world and their views of NOS.

Table 4.15: Theme labels and theme definitions employed in analysing the coherent and incoherent links for all cases, arranged into five clusters

Clusters of themes	Sub-division of cluster	Theme label	Theme definition
1. Knowing and finding out	The past	History	Studying things from the past/history
	About Nature (now)	Find out & Learn	Learning/finding out about Nature, studying things in Nature, knowing things about Nature
	The future	Predicting Nature	Making predictions, knowing what will happen in future (e.g., weather, natural disasters)
2. Sure knowledge	Evidence/proof	Evidence	Finding fossils, proof
	Experimentation	Experiments	Do experiments, do tests, take samples, chemicals and labwork
	Using technology	Technology	Using technology to find out things
	Facts (correct)	Facts & Truth	Finding the truth, the right answer, the facts
	Observations	Search, Explore, Observe	Searching for evidence, exploring places in Nature, go out there, see things in Nature
3. Unsure knowledge	Unknown	Unknown	Lack sufficient information, things that haven't yet been found and and there's more to discover, don't know everything, scientists disagree
	Changes	Change	Nature changes, scientists could change what they tell us
	Errors/doubt	Uncertain, Doubt, Mistakes	Scientists might make a mistake or give wrong information, scientists are unsure about some things, I doubt/mistrust what they say
4. Choosing an explanatory framework	Naturalistic (science) or super naturalistic (religion/God)	Science vs. Religion	Believing God/religious teachings or scientists/science
5. Interactions/ transactions	With knowledge	Legacy of knowledge	Scientific knowledge is passed onto future generations (e.g., knowledge of dinosaurs and medicinal plants)
	With Nature	Emotional response	Nature is dangerous, relaxing in Nature
	With knowledge and Nature	Invent & Develop	Invent/create/develop things, to improve our lives/world

Notably, most of the large number of links within the cluster *Sure knowledge* were coherent (94%). The themes included in this cluster included links related to finding facts by searching for evidence, including observations, experiments and the use of technology. In contrast, the cluster *Unsure knowledge* contained the lowest proportion of coherent links (79%) relative to all the other clusters.

Table 4.16: Numbers (and percentages) of coherent and incoherent links between views of NOS and views of Nature, summarised per theme for all cases

Clusters of themes	Theme label	No. coherent	No. incoherent	Total links	*% coherent*	*% incoherent*
Knowing and finding out	History	4	0	4	*100*	*0*
	Find out & Learn	34	3	37	*92*	*8*
	Predicting Nature	15	7	22	*68*	*32*
Sure knowledge	Evidence	4	0	4	*100*	*0*
	Experiments	8	0	8	*100*	*0*
	Technology	2	0	2	*100*	*0*
	Facts & Truth	11	1	12	*92*	*8*
	Search, Explore, Observe	21	2	23	*91*	*9*
Unsure knowledge	Unknown	27	3	30	*90*	*10*
	Change	4	1	5	*80*	*20*
	Uncertain, Doubt, Mistakes	10	7	17	*59*	*41*
Choosing an explanatory framework	Science vs. Religion	7	8	15	*47*	*53*
Interactions/ Transactions	Legacy of knowledge	5	0	5	*100*	*0*
	Emotional response	2	0	2	*100*	*2*
	Invent & Develop	10	1	11	*91*	*9*

This cluster (*Unsure* knowledge) included links concerning scientists having insufficient information, making mistakes and changing what they tell us, resulting in a lack of uncertainty and even mistrust in scientific knowledge. Earlier, in the section dealing with the NOS results (Chapter 4, page 128), it was reported that the students held the most informed views about the empirically-based aspect of NOS and their views were least informed regarding the theory-laden aspect of NOS. These results might therefore be related.

Overall, the majority of the total links between the students' views of NOS and their views of Nature were coherent (164 links), although there were also a number of incoherent links (33 links) (Table 4.16). In six themes, (from three different clusters) the links were all coherent, namely: *History (Knowing and finding out); Evidence, Experiments, Technology (Sure knowledge),* and *Legacy of knowledge,* and *Emotional response (Interactions/transactions).* In a further six themes (from four different clusters) the links were predominantly coherent with some incoherent links: *Find out and learn (Knowing and finding out), Facts and truth; Search, explore, observe (Sure knowledge), Unknown; Change (Unsure knowledge),* and *Invent and develop (Interactions/transactions)*. However, three themes (from three different clusters) contained a large proportion of incoherent links, namely: *Predicting Nature (Knowing and finding out), Uncertain, doubt, mistakes (Unsure knowledge),* and *Science vs. religion (Choosing an explanatory framework)*. The incoherent links occurring within these last nine themes signal a number of issues that might need to be addressed in science classrooms (concerning not only issues relating to incoherence but also related to internal complexity and coherence) as will be discussed later (Chapter 5, pages 184, 189, 194 and 259).

Analyses of links between the students' views of NOS and their views of the natural world were extended beyond merely identifying themes amongst the contents of the various links, and forming clusters of such themes. In order to explore what the links between the two domains revealed in regard to the students' levels of understanding about each of the five target aspects of NOS, links were further analysed in respect of particular levels of NOS understanding for each NOS aspect, as explained next.

Links of themes with levels of NOS understanding

A cross-case analysis was conducted of all the coherent and incoherent links between the students' views of NOS and their views of Nature. That is, patterns were sought amongst the various links (described in terms of the 15 themes) and each of the levels of understanding regarding the five NOS aspects (Table 4.17). It was found that there were links belonging to a single theme (e.g., *Find out & learn*) that were both coherent and incoherent with various levels of understanding about a single NOS aspect. For example, regarding the theme *Find out and learn*, and views of the theory-laden aspect of NOS, there were coherent links with informed, developing and naive levels of understanding, as well as incoherent links with informed and naive levels of understanding (Table 4.17). That said, however, a number of tentative trends emerged from this cross-case analysis, and these are described next.

Links belonging to the first cluster of themes, namely, *Knowing and finding out*, are concerned with studying the past, studying the present natural world, and knowing about the future. Links in this cluster were largely coherent with informed and developing views of the tentative aspect of NOS. Links in this cluster were also largely coherent with informed views of the empirically-based aspect of NOS, and incoherent with naive views of the imaginative/creative aspect of NOS.

The second cluster of themes, *Sure knowledge*, contains themes relating to finding the facts and the truth, searching for evidence, finding evidential proof, conducting experiments and tests, and using technology to learn about Nature. In this cluster, links were largely coherent with informed views of the empirically-based aspect of NOS. Links in this cluster were also coherent with naive views of the imaginative/creative aspect of NOS, and incoherent with informed views of the imaginative/creative aspect of NOS.

Table 4.17: Summary of numbers of links between students‘ views of NOS and their views of Nature for all 14 cases (detailed in terms of the 15 themes, and per level of understanding for each NOS aspect)

THEMES (PER CLUSTER)	**TENTATIVE**						**EMPIRICAL**						**THEORY**						**SOCIAL/CULTURAL**						**IMAG. / CREAT.**					
	Coherent			**Incoherent**			**Coherent**			**Incoherent**			**Coherent**			**Incoherent**			**Coherent**			**Incoherent**			**Coherent**			**Incoherent**		
	I	D	N	I	D	N	I	D	N	I	D	N	I	D	N	I	D	N	I	D	N	I	D	N	I	D	N	I	D	N
Knowing & finding out	**8**	**5**	**1**				**28**	**5**	**2**	**11**			**1**	**2**	**3**	**2**	**2**	**2**		**1**	**2**			**1**			**1**			
History		1					3																							
Find out & learn	5	2	1				19		2	3			1	1	2	2		1		1	2			1			1			
Predicting Nature	3	2					6	5		8				1	1			1												
Sure knowledge	**1**	**1**	**1**				**35**	**4**	**1**	**1**			**6**		**9**		**1**		**3**	**2**	**3**			**2**	**3**		**9**	**1**		
Evidence							4	2					1		2		1			2					1					
Experiments			1				6						1																	
Technology		1					3																		1					
Facts & truth							5	2					4		2				3					2	1		3			
Search, explore, observe	1						17		1	1					5						3						6	1		
Unsure knowledge	**9**	**2**		**1**		**2**	**10**	**1**	**1**		**2**	**3**	**10**	**1**	**5**	**1**		**3**	**5**	**5**	**4**			**1**	**4**		**1**	**1**		**1**
Unknown	4					2	7	1	1				8		4				5	2	3				3		1			
Change	4			1																										
Uncertain, doubt, mistakes	1	2					3				2	3	2	1	1	1		3		3	1			1	1			1		1
Choosing an explanatory framework	**2**	**1**		**1**		**1**	**1**			**5**			**1**		**1**	**1**		**3**	**2**	**1**				**2**	**2**					**4**
Science vs. religion	2	1		1		1	1			5			1		1	1		3	2	1				2	2					4
Interactions/ transactions	**3**	**3**	**3**	**1**			**4**		**1**					**2**	**1**				**1**						**6**		**1**			
Legacy of knowledge			3				1							1	1												1			
Emotional response		2																												
Invent & develop	3	1		1			3		1					1					1						6					

The third cluster, *Unsure knowledge*, includes themes relating to unknown aspects of the natural world, things that change, and uncertain and mistaken information. These themes contained links that were coherent with informed and developing views of the tentative aspect of NOS. This cluster also contained links that were largely coherent with informed views of the empirically-based NOS aspect, and incoherent with naive and developing views of the empirically-based aspect of NOS.

Choosing an explanatory framework is the fourth cluster, which relates to the theme of believing science or religious teachings. Links belonging to this theme included those that were coherent with informed and developing views of the socially- and culturally-embedded aspect of NOS, and incoherent with naive views of the socially- and culturally-embedded aspect of NOS. Links in this cluster were also coherent with informed views of the role of imagination and creativity in science, and incoherent naive views of the imaginative/creative aspect of NOS.

Fifth, the themes clustered as *Interactions/transactions* are concerned with passing on a legacy of knowledge, students' emotional responses to the natural world, and inventing and developing things to improve people's lives and/or to improve Nature. Themes in this cluster contained links that were coherent with informed views of the socially- and culturally-embedded NOS aspect (with regard to inventing and developing things). Links in this cluster were also largely coherent with the empirically-based and imaginative/creative aspects of NOS. Furthermore, this cluster contained links that were coherent with developing and naive views of the theory-laden aspect of NOS.

From the above analysis of coherent and incoherent links belonging to each cluster of themes, some possible relationships might be suggested concerning the students' worldview descriptions and their views of NOS. For example, informed views of the tentative aspect of NOS are coherent with ideas concerning knowing and finding out about Nature, and about knowledge that is uncertain, whilst ideas concerning knowledge that is certain are coherent with informed views of the empirically-based aspect of NOS and incoherent with informed views of the role of imagination and creativity in science.

However, the results of this cross-case analysis provide somewhat limited insights into the interplay between the students' NOS views and their worldviews their NOS views. Therefore more detailed data analyses were conducted of the various links between the students' views of NOS and of Nature, for all cases. Specifically, the researcher sought to determine if there were links in common (albeit coherent or incoherent links) between particular descriptions of the

Table 4.18: Numbers of **coherent** links between worldview descriptions (bipolar descriptors) and NOS aspects (levels of understanding) for all 14 cases

DESCRIPTORS PER WORLDVIEW DESCRIPTION		LEVELS OF UNDERSTANDING PER NOS ASPECT																
		Tentative			**Evidence**			**Theory**					**Soc. / Cult.**			**Imag./ Creat.**		
		I	**D**	**N**	**I**	**D**	**N**	**I**	**D**	**N**	**I&N**	**D&N**	**I**	**D**	**N**	**I**	**D**	**N**
EPISTEMOLOGICAL	Knowable	4	2	4	32	1	3	4	1	5	1	1	1	3	2	2		5
	Unknowable	7	4		13	5	1	5	1	5			3	3	5	5		1
	Knowable & Unknowable	1	1		8			1		2			2	1	1	2		1
ONTOLOLOGICAL	Naturalistic	3	1		6	1		1										1
	Super-naturalistic	2	2		2	2		1	1	3			2	2		2		1
	Naturalistic & Super-naturalistic				1	1		2					2					
EMOTIONAL	Positive	1	1		7			1										
	Neutral																	1
	Negative	1	1		2					1					1			
	Neutral & Negative	1																
STATUS	Resource-oriented	2		1	5											3		
	Conservationist	1			2		1	1	1		1		1			1		2

KEY: I = Informed, D = Developing; N = Naive

Table 4.19: Numbers of **incoherent** links between worldview descriptions (bipolar descriptors) and NOS aspects (levels of understanding) for all 14 cases

DESCRIPTORS PER WORLDVIEW DESCRIPTION		**LEVELS OF UNDERSTANDING PER NOS ASPECT**															
		Tentative			**Evidence**			**Theory**				**Soc. / Cult.**			**Imag. / Creat.**		
		I	**D**	**N**	**I**	**D**	**N**	**I**	**D**	**N**	**I&N**	**I**	**D**	**N**	**I**	**D**	**N**
EPISTEMOLOGICAL	Knowable	1			2		1	1	1					2	1		
	Unknowable			1	9	1	1	1		4				2			1
ONTOLOLOGICAL	Naturalistic				1	1											
	Super-naturalistic	1		1	2		1			2	1			1			2
	Naturalistic & Super-naturalistic				1									1			1
EMOTIONAL	Positive				2			1									1
	Neutral																
	Negative	1								1					1		
	Positive & Negative			1													
STATUS	Resource-oriented																
	Conservationist																

Key: I = Informed, D = Developing; N = Naive natural world (e.g., naturalistic) and particular levels of understanding pertaining to particular NOS aspects (e.g., informed views of the empirically-based aspect of NOS). A summary of the results is presented in Table 4.18 and Table 4.19. Again, no clear patterns were found. For example, in some cases the students‘ unknowable worldview descriptions were coherent with both informed and naive views of the imaginative/creative aspect of NOS, as well as being incoherent with naive views regarding this NOS aspect.

The results described in this section highlight that the relationship between the students‘ views of the natural world and their views of NOS is complex. However, there remains a need to understand why science students do not hold an informed understanding of NOS, and how their NOS views are related to their worldviews. To this end, a further, in-depth analysis was conducted of selected links between the students‘ views of NOS and their views of Nature, and this revealed a number of significant issues pertaining to students‘ views of the natural world and their understanding of NOS. These results are presented in the next section.

Identifying issues arising from themes of links between worldviews and NOS views

In order to improve students‘ understanding of NOS, there is a need to understand why they do not hold informed NOS views, and how their worldviews might be related to their NOS views. Particular areas of difficulty can be identified and addressed by examining students‘ naive NOS views as well examining incoherent links between their NOS views and their worldviews. Accordingly, further in-depth analysis of the relationships between the students‘ NOS views and their views of the natural world focussed on the *coherent* links between the students‘ *naive* NOS views and various worldview descriptors, as well as the *incoherent* links between the students‘ *informed* NOS views and various worldview descriptors. The results of this focussed analysis are presented here. Links are described in relation to the 15 themes mentioned earlier (page 181), and organised in relation to the five NOS aspects (i.e., tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative and creative). A synopsis of the issues emerging from these various links is presented here. Evidence of the contents of the links is provided in Appendix 4.9 (page 410).

Tentative, subject to change

Coherent links between *naive* views of the tentative aspect of NOS and epistemological and status descriptions of the natural world revealed an issue relating to our knowledge of the natural world (i.e., whether scientists already know everything about the natural world [Figure 4.18]), an issue concerning the reliability of scientific knowledge (i.e., how scientific knowledge can change if it is to be passed on to future generations [Figure 4.19]), and an issue concerning how scientists study Nature in their work (i.e., how scientists can remove natural resources to use, whilst conducting experiments for sustainability [Figure 4.20]).

SUMMARY STATEMENT

We already know so much about nature from what scientists have been telling us, and the facts don't change. If the facts were to change, scientists wouldn't tell us because then we wouldn't believe them. (Find out & learn) (Brian)

NOS

If they tell the public about the facts and scientists change the facts then people won't believe scientists.

The facts don't change. And if they did, they wouldn't tell us about it.

NATURE

We already know what is going on and what will happen…We see so much of one thing that we already know so much about it...So Nature is also not mysterious because most of it we already know. We haven't found out that many new things about Nature, and finding out new things about Nature would make it seem mysterious *(i.e., it is not mysterious)*. I have learnt what I know about Nature from school. Scientists have discovered Nature and studied it and they've been telling us, so that's how we know things.

Do scientists already know everything about the natural world?

COHERENCE PRINCIPLE

Symmetry

Figure 4.18: Coherent link between naive NOS view and Knowable statement about Nature, relating to the theme *Find out and learn*

SUMMARY STATEMENT

Scientific knowledge doesn't change, because the knowledge is passed on to future generations so it needs to be correct before it is made public. (Legacy of knowledge) (Aamir)

NOS

They have to have everything right about the things they discovered (e.g., before it's in the newspaper and the whole world [knows]…)

NATURE

The natural environment should be studied to pass on the legacy when people die (e.g., plant names).

If scientific knowledge is to be passed onto future generations, how can this knowledge change?

COHERENCE PRINCIPLE

Symmetry

Figure 4.19: Coherent link between naive NOS view and Knowable statement about Nature, relating to the theme *Legacy of knowledge*

From *incoherent* links between *informed* views of the tentative aspect of NOS and epistemological, ontological and emotional worldview descriptions there emerged an issue related to the role/purpose of science (i.e., whether it is necessary to study Nature [Appendix 4.9, Figure A4.9-1, page 410]), an issue concerning predictions about the natural world (i.e., reluctance to accept predictions of negative events in Nature [Appendix 4.9, Figure A4.9-2, page 410]), as well as an issue concerning alternative knowledge frameworks/domains (i.e., how to make sense of explanations about the natural world other than those provided by science [Appendix 4.9, Figure A4.9-3, page 411]).

SUMMARY STATEMENT

People chop down trees to use them, but they might experiment on them beforehand. (Experiments) (Yamina)

NOS

Tree—they might want to experiment on it and make it grow more before they cut it down. What they find out about the tree will not change.

NATURE

…You might see the trees are chopped down over here, but you'll just see in the other area there's trees. You can use the trees for paper and to make desks and doors and houses.

How can scientists simultaneously conduct experiments for sustainability of resources and remove/extract natural resources for use?

COHERENCE PRINCIPLE

Symmetry

Figure 4.20: Coherent link between naive NOS view and Resource-oriented statement about Nature, relating to the theme *Experiments*

Empirical evidence

Coherent links between *naive* views of the empirically-based aspect of NOS and epistemological and status worldview descriptions revealed an issue concerning how Nature is studied in scientists' work (i.e., the kinds of work that scientists do [Appendix 4.9, Figure A4.9-4, page 411]), an issue regarding the means by which scientists obtain the knowledge that they publicise [Appendix 4.9, Figure A4.9-5, page 412], as well as revealing an issue concerning natural phenomena that are intangible and invisible (i.e., whether scientists work with parts of the natural world that are intangible and invisible [Appendix 4.9, Figure A4.9-6, page 412]), and an issue concerning the accuracy and reliability of scientific knowledge (Appendix 4.9, Figure A4.9-7, page 412).

From *incoherent* links between *informed* views of the empirically-based aspect of NOS and epistemological, ontological and emotional descriptions of the natural world there emerged an issue concerning the predictability of Nature (i.e., whether Nature is predictable, and whether scientists can predict natural events [Appendix 4.9, Figure A4.9-8, page 413], an issue regarding how Nature is studied in scientists' work (i.e., how exactly scientists go about their work and develop knowledge about the natural world [Appendix 4.9, Figure A4.9-9, page 413]), as well as issues concerning the role/purpose of science (i.e., Why we need to understand Nature better, and how increased understanding might affect our enjoyment and appreciation of Nature [Appendix 4.9, Figure A4.9-10, page 414], and why the study of Nature is privileged to science when the natural world is visible and accessible to everyone [Appendix 4.9, Figure A4.9-11, page 414]). Issues also emerged concerning alternative knowledge frameworks/domains (i.e., the kinds of questions that science can answer

[Appendix 4.9, Figure A4.9-12, page 415], demarcating the domain of scientific knowledge as opposed to religious beliefs [Appendix 4.9, Figure A4.9-13, page 415], which knowledge framework we should draw upon in trying to understand natural phenomena [Appendix 4.9, Figure A4.9-14, page 416], and how to make sense of scientific knowledge when there are conflicts with personal religious beliefs [Appendix 4.9, Figure A4.9-15, page 416]).

Theory-laden, subjective

Coherent links between *naive* views of the theory-laden aspect of NOS and epistemological, ontological and emotional descriptions of the natural world revealed an issue relating to predictions of the natural world (i.e., making sense of scientific predictions and forecasts [Appendix 4.9, Figure A4.9-16, page 417]). Issues also emerged concerning uncertainties and lack of evidence in science (i.e., how scientists can tell us things about which they have only have partial knowledge [Appendix 4.9, Figure A4.9-17, page 417], and how to make sense of scientific knowledge that is not based on facts [Appendix 4.9, Figure CT-18, page 418] and for which there is insufficient evidence [Appendix 4.9, Figure A4.9-19, page 418]), and concerning the reliability of scientific knowledge (i.e., the trustworthiness of the empirical data upon which scientific knowledge is based, in light of the possibility that scientists are people that can make mistakes [Appendix 4.9, Figure A4.9-20, page 419], and how to regard scientific knowledge, which might contain errors, when it conflicts with personal religious beliefs [Appendix 4.9, Figure A4.9-21, page 419]).

Incoherent links between *informed* views of the theory-laden aspect of NOS and epistemological and emotional worldview descriptions revealed an issue concerning intangible/unobservable natural phenomena (i.e., how we can know about things in Nature that we cannot observe and experience first-hand, including knowledge of the history of the world [Appendix 4.9, Figure A4.9-22, page 420]), and an issue relating to the role/purpose of science (i.e., why we need to know more about the natural world [Appendix 4.9, Figure A4.9-23, page 420]).

Socially- and culturally-embedded

From *coherent* links between *naive* views of the socially- and culturally-embedded aspect of NOS and epistemological and emotional worldview descriptions there emerged a number of issues concerning our knowledge of the natural world (i.e., how much of Nature we can know and understand [Appendix 4.9, Figure A4.9-24 and Figure A4.9-25, page 421]) and concerning uncertainties about the natural world (i.e., how scientists deal with natural phenomena that cannot be understood and/or explained [Appendix 4.9, Figure A4.9-26, page 422], and how to make sense of the notion that some scientific knowledge is uncertain when we need to be able to trust it and apply it [Appendix 4.9, Figure A4.9-25, page 421]). An issue also emerged concerning the relationship between empirical evidence and scientists own thoughts and ideas [Appendix 4.9, Figure A4.9-27, page 422], as well as issues relating to disagreements in science (i.e., the causes of disagreements amongst scientists, how their disagreements are resolved [Appendix 4.9, Figure A4.9-28, page 423], and whether multiple possible answers can be valid in science [Appendix 4.9, Figure A4.9-24, page 421]).

There were no *incoherent* links with *informed* views of the socially- and culturally-embedded aspect of NOS.

Imagination and creativity

Coherent links between *naive* views of the role of imagination and creativity in science and all four worldview descriptions revealed an issue concerning the role/purpose of science (i.e., why we need to develop knowledge about the natural world (Appendix 4.9, Figure A4.9-29, page 423]), and issues concerning truth and proof (i.e., what is *truth* [Appendix 4.9, Figure A4.9-30, page 424] and what is *proof* [Appendix 4.9, Figure A4.9-31, page 424], and whether super-natural phenomena can be proven to exist ([Appendix 4.9, Figure A4.9-31, page 424]). Issues were also revealed relating to the relationship between empirical evidence and scientists' own ideas and imaginations (Appendix 4.9, Figure A4.9-30 [page 424], and Figure A4.9-32 and Figure A4.9-33 [page 425]) and relating to the relationship between imagination/creativity in science, and fiction (Appendix 4.9, Figure A4.9-34, page 426). Further issues emerged concerning knowledge of invisible and intangible natural phenomena (Appendix 4.9, Figure A4.9-35, page 426), and concerning making predictions about the natural world (i.e., how forecasts and predictions are made in science [Appendix 4.9, Figure A4.9-33, page 415]).

Incoherent links between *informed* views of the role of imagination and creativity in science and epistemological and emotional worldview descriptions revealed an issue concerning the relationship between empirical evidence and scientists' own ideas and imaginations (i.e., Appendix 4.9, Figure A4.9-36, page 427), an issue concerning imagination and creativity in science and mis-information (i.e., distinguishing between the use of imagination/creativity in science, and trickery [Appendix 4.9, Figure A4.9-36, page 427]), as well as an issue relating to diversity and patterns in the natural world (i.e., how to make sense of diversity in Nature whilst experiencing natural phenomena that are familiar to us and which share common characteristics [Appendix 4.9, Figure A4.9-37, page 427]).

There is some overlap and repetition amongst the issues that arose from this analysis and pertaining to each of the five NOS aspects. Broadly speaking, these various issues are related to the following topics: the role/purpose of science; natural diversity and patterns in Nature; the nature of scientists' work; the limits to our knowledge of the natural world; the ability to make predictions about Nature; making sense of uncertainties, intangibles and a lack of evidence in science; the reliability of scientific knowledge; truth and proof; the relationship between empirical evidence and scientists' own ideas and imaginations; the relationship between imagination/creativity and mis-information; disagreements amongst scientists, as well as issues relating to alternative knowledge frameworks/domains (a summary of these twelve topics is presented in Chapter Five, page 246 [Table 5.3]). These issues are significant for understanding the relationships between students' NOS views and their views of the natural world, and for determining how science educators might help their students to develop a more informed understanding of NOS. This is discussed further in Chapter Five (page 258).

In addition to the above-mentioned results pertaining to coherent and incoherent links between the students' statements about NOS views and about Nature, there were found to be students who articulated differences and conflicts between their personal worldviews, including their religious beliefs) and science. Results relating to the coherence between students' NOS views and their experiences of worldview conflicts are presented next.

Coherence between NOS views, and instances of System complexity and System incoherence within students' descriptions of the natural world

Within six students' views of the natural world, there were found to be instances of system complexity and system incoherence relating to border-crossing issues (e.g., conflicts between science and religion) (pages 163, 170 and 194). It is beyond the scope of the present study to analyse these students' border-crossings types and collateral learning strategies in-depth. However, in order to explore fully the coherence between students' views of the natural world and their NOS views, analyses were conducted in order to determine the coherence between these six students' NOS views and instances of system complexity/incoherence within their worldview descriptions relating to border-crossing and science-religion conflicts. The results for the six students are presented here (i.e., Shanon, Victoria, Gideon, Shafia, Dyllan, and Brian).

Shanon

In Shanon's description of her views about the natural world, she acknowledged the existence of opposing explanations about Nature (―Either God made Nature or something else made it, something scientific. Religion and science clash.”). She tried to make sense of the different theories (―It‘s like God created the world in seven days, and, the world was built up by lots of different minerals forming together. And there‘s so many different theories that you don‘t know which one to choose.”). Similarly, in describing her views of NOS, Shanon mentioned that scientists have different theories, some of which are correct whilst others are inaccurate (―They have different theories....A [theory] is something that you‘re trying to prove yes, it‘s right or no, it‘s wrong.”). As such, Shanon‘s worldview descriptions were coherent with her NOS views, and the explanatory coherence principle of explanation (Chapter 3, page 99) was applied concerning her views about the existence of various theories. However, Shanon was unsure of which theory to choose, and therefore she compartmentalized the various explanations, and moved between them as needed (―So when it‘s time for religion learning then you just switch your mind to religion, and when it‘s time for science you switch your mind to science. Because you know that you kind of believe in both in a way. Or you want to. I love my religion but I also love science. You can‘t really choose between them”). This compartmentalization of views indicated Shanon‘s use of ‗parallel collateral learning‘ in order for her to negotiate ‗managed‘ border-crossings (Chapter 2, page 41 and page 42).

Victoria

In describing her NOS views, Victoria recognised that disagreements might arise between people because their opinions differ, and therefore various theories exist (―Some of the scientists believe different facts and that then makes them theories...And that‘s…why they might disagree, because…they might have slightly different opinions.”). She went on to describe how scientists are uncertain of their knowledge (―…they‘re sometimes a little bit unsure, because…scientists have their own opinions, their different opinions. That‘s why they‘re a little unsure…”). Similarly, Victoria‘s view of Nature reflected uncertainty about the accuracy of various explanations about Nature (―…God created the Earth, although we don‘t know for sure it was created.”). Her NOS statements and worldview statements were therefore coherent, and the explanatory coherence principle of explanation (Chapter 3, page 99) was applied concerning the existence of different explanations and her feelings of uncertainty about the various accounts. However, whilst Shanon compartmentalized conflicting explanations, Victoria chose to combine them (―I believe that God created the Big Bang and then started evolution.”). As such, Victoria held what Edis (2009) referred to as a *compromise view* of Nature, and as such, her border-crossings seemed to be ‗managed‘, by means of ‗secured collateral learning‘ (Chapter 2, page 41 and page 42).

Gideon

In describing his views of NOS, Gideon stated that although disagreements exist amongst scientists, it is accepted that explanations will always differ (―They just accept there will always be different answers.”). Similarly, in describing his view of the natural world, Gideon provided an example of conflicting accounts of the existence of particular mountains, and expressed uncertainty about which account to believe (―There are many things in the Jewish Torah that I seem to not understand about Nature. Because it says in the Torah, there were mountains that have been searched for and searched for many years and not been found. So the question is: Did they just disappear? Is what‘s in the Torah true? That‘s another question!”). Thus, Gideon‘s NOS statements were coherent with his worldview descriptions regarding conflicting explanations about natural phenomena, and the explanatory coherence principle of explanation (Chapter 3, page 99) was applied.

In dealing with the uncertainty of which account to believe, Gideon described a combination of super-naturalistic and naturalistic explanations about Nature.

> Nature is just there, it is. But the question is, did we do something to create Nature, or was it just there when we were created? I believe that He created the world, but I think that Nature‘s something that controls itself. I do believe in God, but I don‘t really see the work of God in Nature…

As such, Gideon described a compromise view of the natural world (as was the case with Victoria) (―What is Nature created by?...I think it‘s possible—I‘m not saying that I totally believe this—it‘s possible, that Nature‘s created by God. But I think that once Nature‘s created, if it‘s by God or not, it‘s now controlled by itself.”). As was the case with Victoria, Gideon‘s border-crossings seemed to be ‗managed‘ by means of ‗secured collateral learning‘ (Chapter 2, page 41 and page 42).

Shafia

In her views of the natural world, Shafia described opposing accounts of the origin of Earth (―Before we started on this Earth, everything here was Nature. The scientists say that there was a Big Bang, but in our religion we say that Allah made the Earth, the stars and everything.”). However, she acknowledged the possibility that both scientific and religious explanations could be correct, which was evidence of a *compromise view* of Nature:

> …if it was the Big Bang, how did the Earth, the planets get there in the first place? There could have been a Big Bang, but if there was a Big Bang there must have been something, the person who made the thing before the Big Bang. The scientists don‘t know what to say about that. That‘s why we say that Allah created it…The scientists could be right *and* we could be right.

Similarly, in describing her views of NOS, Shafia stated that scientists are sometimes correct and they can be trusted, whilst also expressing some uncertainty about scientific knowledge (―We trust [scientists], but we‘re not sure…Sometimes they have a few facts and it‘s sometimes right. But we can‘t always be sure.”). Overall, Shafia‘s religious beliefs were stronger than her belief in science (―I believe in my religion very strongly.”; ―The more facts [scientists] have, the more we trust them. At the moment, we‘re not sure…”). Nonetheless, Shafia‘s worldview statements and NOS statements were coherent, and the principle of explanation (Chapter 3, page 99) was applied concerning her uncertainty about the various accounts. Moreover, Shafia‘s compromise view and her acknowledgment of alternative explanations, indicated the possible use of ‗simultaneous collateral learning‘ in order to negotiate border-crossings that were ‗managed‘ (Chapter 2, page 41 and page 42).

Dyllan

In describing his views about the natural world, Dyllan expressed feelings of mistrust of scientists, a lack of belief in what scientists say, and a view that scientists make mistakes. In describing these views, Dyllan articulated conflict between what he was taught in school science and his religious beliefs:

> Our teacher says in science that scientists say the sun is going to blow up or it is going to fall into itself, or the Earth is going through the same thing, but in one billion years. That‘s quite a long time. But I don‘t trust what they tell us, because when I go to church, they sing a hymn where the last line says, ―world without end” and it goes ―Amen”. So I think if God says there will be no end, I think that‘s right. I don‘t believe the scientists. They are not super-humans. They also make mistakes, so maybe they‘re wrong about the world ending.

Likewise, in describing his NOS views, Dyllan expressed mistrust in scientists‘ accounts of the galaxy (―…they took a picture of the Milky Way galaxy how it looks in space. But the Voyager 1 only passed Pluto now! …And that‘s the first one that we sent out, so…maybe they‘re tricking us.”) and dinosaurs (―Archaeologists found…fossils of the dinosaurs, but obviously the skin has been eaten up…what if they are fooling us by just putting on skins but with the shape of the dinosaur‘s body and then they find another one and just put, just make his skin colour green. But if you go back in time it‘s red…?”). Dyllan also expressed a lack of belief in what scientists tell us about outer space (―Scientists say that the Space comes to an end. I really don‘t believe. I think it goes on forever.”), and a view that scientists make mistakes:

> ...Voyager 1 that was sent out so they can experience our solar system, Mr. [B] says it‘s only gone passed Pluto now…And that it‘s shut down because it works off solar power and now it‘s not getting any sun because it‘s past Pluto. So, maybe, maybe it‘s not past Pluto. I don‘t know…It‘s strange. Or maybe…as they passed Pluto another sun came so it was still on. It‘s quite confusing! …Say the Voyager 1 passed Pluto and now it‘s shut down, its not getting any sunlight and now it‘s travelling for a long time and there‘s a planet that looks similar to Pluto or maybe has the same structure as Pluto and now they get sunlight again and they say, ―Ah, it it‘s just past Pluto, and it receives light from somewhere else.” But it‘s not Pluto. It‘s, like, a different planet.

These NOS statements from Dyllan were therefore coherent with his worldview descriptions, and the principle of symmetry (Chapter 3, page 98) was applied concerning his mistrust of scientists, lack of belief in scientific explanations, and erroneous accounts in science.

In addition to the conflict that Dyllan described between science and religion, he articulated conflict between school science and what his parents taught him at home. This conflict between school and home was a source of confusion for him:

> [Re: Is what science tells you the absolute truth?] Mmm, no. M'am, because…Mr. [B] says if I go out to space…swim in space…it's a pool. Then, Mr. [B] said I will see stars and I will see comets and I will see…maybe a dwarf sun or something like that, m'am. And then my Dad says different. He says if I go out to space I will just see blackness unless there is a planet in front of me. So that's why I say, m'am, I don't- you see, it's confusing like that, m'am…

Dyllan's confusion was also related to the natural world, as he considered that Nature comprised elements that are unexplained (―There is some stuff in Nature that we can't give an explanation for.") Overall, he viewed Nature as being equally confusing and understandable (―…‗I say it's equal…Because…if there was [more stuff that's confusing] then science would be short, and then also…probably in some way then we wouldn't have science ‗because there's not much to talk about if there was more that's confusing..."). Again, Dyllan's NOS statements were coherent with his worldview descriptions, although in his case the principle of explanation (Chapter 3, page 99) was applied concerning confusion about Nature and the study thereof (i.e., science). In contrast to the previous four cases, however, border-crossings seemed ‗hazardous' for Dyllan, as for him, the alternative explanations he considered seemed incompatible (Chapter 2, page 41 and page 42).

Brian

In Brian's views of Nature, he described how people tell different stories to explain natural phenomena, but that some accounts are untrue. As was the case with Dyllan, Brian said he preferred to believe explanations involving God rather than believing scientists' accounts:

> Scientists always have an explanation or an answer to why, like, why did we have animals, and why there were cavemen and things like that. And they always try to prove people wrong. But some people believe in God, and they tell stories about God that we believe more than we believe what the scientists tell us…I'd rather believe in God.

Brian's preference for religious beliefs over scientific explanations was also reflected in his views of NOS, in that he described a view that scientists fabricate explanations. Consequently, Brian felt unsure about scientific knowledge (―I think that they would make up stories so that people would think that they are clever...or right…They might not be sure, like really sure. But they're certain. They're certain of what they tell us but we're not certain about it/them."). As such, Brian's statements concerning his views of the natural world were coherent with his views of NOS, regarding uncertainty and lack of belief in scientists' explanations about Nature. Here, the explanatory coherence principle of symmetry (Chapter 3, page 98) applied.

Furthermore, due to the incompatibility that Brian perceived between his religious beliefs and science, border-crossings seemed ‗impossible' for him (Chapter 2, page 41 and page 42).

In summary, analysis of the coherence for these six students revealed that although their worldview descriptions contained instances of system complexity and system incoherence (relating specifically to border-crossing issues and conflicts between science and religious beliefs), these worldview descriptions were coherent with their views of NOS.

Some emerging insights relating to instances of system complexity/incoherence within the students' views of Nature and of NOS, can be further gained from a comparison of these data with instances of explicit conflict and/or compromise views, collateral learning strategies and the types of ways in which students' resolved their worldview conflicts, as well as the types of border-crossings that students seemed to be experiencing (e.g., between science and their religious beliefs). Such a comparison is presented in Table 4.20.

On the one hand, Victoria, Gideon and Shafia described views of the natural world that contained instances of system complexity. Their border-crossings were ‗managed', by means of compromise views. That is, different worldviews were kept separate, but there was some interaction between the alternative explanatory frameworks. Victoria, Gieon and Shafia held NOS views that were largely informed overall. On the other hand, Shanon's view of the natural world contained instances of system complexity, and she also articulated an explicit conflict between science and religion. Her border-crossing was ‗managed', but by keeping the different explanatory frameworks separate and without interaction between the two worldviews. Shanon's NOS views were somewhat informed overall. In contrast, Dyllan's and Brian's views of Nature contained instances of system incoherence. In both cases, these students articulated explicit conflicts between science and religion. For them, border-crossings were ‗hazardous' or ‗impossible', as the conflicting worldviews were incompatible, and therefore one worldview (e.g., religion) was selected to dominate over the other. Overall, the NOS views of Dyllan and Brian were only developing.

It would seem, therefore, that the students who were able to resolve their worldview conflicts and therefore to ‗manage' their border-crossing experiences (e.g., between science and their religious views), held NOS views that were overall more informed than the students for whom different worldviews seemed incompatible, and for whom explicit conflicts could not be resolved or managed in some way.

Table 4.20: Summary of instances of system complexity/incoherence, explicit conflicts and compromise views, collateral learning strategies, types of resolutions to worldview conflicts, border-crossing types pertaining to six cases, as well as students' overall levels of NOS understanding

Case name	System complexity/ incoherence (views of Nature)	Explicit conflict	Compromise view	Collateral learning strategy	Resolution to worldview conflict	Type of border-crossing	Overall levels of NOS understanding
Victoria	System complexity		✓	Secured	Separate, independent, communicative	Managed	(Largely) Informed
Gideon	System complexity		✓	Secured	Separate, independent, communicative	Managed	(Largely) Informed
Shafia	System complexity	✓	✓	Simultaneous	Separate, independent, communicative	Managed	(Largely) Informed
Shanon	System complexity	✓		Parallel	Separate, independent, non-communicative	Managed	(Somewhat) Informed
Dyllan	System incoherence	✓		Simultaneous	Incompatible: Religion dominates over science; School dominates over home	Hazardous	Developing
Brian	System incoherence	✓		Simultaneous	Incompatible: Religion dominates over science	Impossible	Developing

In addition to the above results relating to coherence *between* the students' views of the natural world and their views of NOS, coherence analyses also concerned the extent to which the students' views were coherent *overall*, as presented next.

Overall coherence of the students' views

The extent to which the Grade Six students' views could be considered to be coherent overall was determined by looking at the instances of system complexity and system incoherence within the students' NOS views, instances of system complexity and system incoherence within students' views of the natural world, incoherent links between students' statements about NOS and their statements about Nature, and any explicit conflicts that individuals articulated (Chapter 3, page 97). As previously explained (page 178), the results concerning each of these various components of the analyses of coherence have already been presented in detail (page 130 and page 162). Therefore, in considering the overall coherence of the students' views in the following section, synopses of the relevant components of these coherence results have been included.

System complexity & System incoherence *within* students' views of the natural world and *within* their views of NOS

Instances of system complexity and system incoherence were identified within eight of the fourteen students' views of NOS (Table 4.21). Within the students' views of the natural world, instances of system complexity and system incoherence were identified in the views of ten of the students (Table 4.21). Aamir was the only student for whom there were no instances of system complexity/incoherence within either his NOS views or his views of Nature—although there were incoherent links between his views of the two domains, as discussed later (page 204).

Most of the instances of worldview system complexity and system incoherence were found within the students' epistemological descriptions (19)[14], followed by their ontological WV descriptions (15)[14]. There were only a few instances of system complexity and/or system incoherence within the students' emotional descriptions (two instances) and status descriptions (one instance) of the natural world. Overall, there were more than twice as many instances of system complexity/incoherence within the students' views of the natural world (37) than within their NOS views (16). It could therefore be said that the students' NOS views were more

[14] One instance of system complexity was found within Samuel's view of the natural world, relating to both epistemological and ontological descriptions of Nature. Similarly, one instance of system incoherence was found within Maya's view of the natural world, relating to both epistemological and ontological descriptions of Nature (Table 4.21).

Table 4.21: Numbers of instances of system complexity and system incoherence within the students‘ views of the natural world and within their views of NOS

	VIEWS OF THE NATURAL WORLD											**NOS VIEWS**		
	System complexity					**System incoherence**						**System complexity**	**System incoherence**	
Case name	Epistemo-logical	Onto-logical	Epistemo-logical & Onto-logical	Emo-tional	Status	Epistemo-logical	Onto-logical	Epistemo-logical & Onto-logical	Emo-tional	Status	***TOTAL***			***TOTAL***
Aamir											*0*			*0*
Shafia		1									*1*			*0*
Maya	1										*1*			*0*
Reza								1			*1*			*0*
Gideon	1	1									*2*	1		*1*
Dyllan	1	1									*2*		1	*1*
Shanon		2									*2*		5	*5*
Yamina						2					*2*		1	*1*
Victoria	1	1			1						*3*			*0*
Aaeesha	1						2				*3*			*0*
Dan				1		2					*3*		1	*1*
Brian						2	2				*4*		3	*3*
Raashid	2					3					*5*		2	*2*
Samuel	2	4	1	1							*8*	2		*2*
TOTAL	**9**	**10**	**1**	**2**	**1**	**9**	**4**	**1**	**0**	**0**	***37***	**3**	**13**	***16***

Table 4.22: Summary of results pertaining to the overall coherence of each student's views, that is, regarding coherence within students' views of the natural world and within their views of NOS, and incoherent links between these two domains, as well as cases where explicit conflicts and compromise views were articulated

CASE NAME	**WITHIN WV**				**WITHIN NOS**			**BETWEEN WV & NOS**
	System complexity: no. of instances	System incoherence: no. of instances	Explicit conflict	Compromise view	System complexity: no. of instances	System incoherence: no. of instances	Explicit conflict	% Incoherent links
Dan	1	2				1		0
Maya	1							0
Aaeesha	1	2						0
Shafia	1		✓					6
Aamir								10
Reza		1						12
Raashid	2	3				2		13
Dyllan	2		✓			1	✓	17
Gideon	2			✓	1			21
Samuel	8			✓	2			23
Victoria	3		✓	✓				25
Yamina		2				1		27
Shanon	2		✓	✓		5		28
Brian		4	✓			3		29

internally consistent than their views of Nature. In addition, there was evidence of internal incoherence in the form of explicit conflicts and compromise views within some students‘ descriptions of the natural world, as presented next.

Conflicts and compromise views

In describing their views of the natural world, a number of the students articulated explicit conflicts between science and religion, whilst some students presented a compromise view in their ontological descriptions of Nature. In addition, one student (Dyllan) articulated explicit conflict between what was taught in school science and what was taught about science at home. These instances of explicit conflicts and compromise views were regarded as additional instances of incoherence within the students‘ conceptual frameworks (Table 4.22).

Incoherence *between* views of the natural world and views of NOS

Further to the instances of system complexity and system incoherence within the students‘ views of Nature and their views of NOS, and explicit worldview conflicts, there were incoherent links *between* the students‘ views of the two domains. In only three cases (i.e., Aaeesha, Dan, Maya) were all the links between students‘ views of Nature and of NOS coherent. In most cases (i.e., 11 of the fourteen cases) there were a number of incoherent links between their views of Nature and their NOS views. In four cases (i.e., Brian, Shanon, Yamina, Victoria), the number of incoherent Nature-NOS links amounted to 25% or more of the total links between students‘ views of NOS and their views of Nature (Table 4.23).

The students‘ views of the natural world and their views of NOS constitute inter-related elements of their conceptual frameworks. Consequently, the various incoherent links that were identified between the students‘ views of the natural world and their views of the NOS were regarded as evidence of internal inconsistency within individuals‘ conceptual frameworks.

In conclusion, therefore, none of the students‘ views were completely coherent overall. In each case there was either an instance of incoherence within a set of views (i.e., system complexity or system incoherence, within students‘ views of Nature or their views of NOS, or within both), incoherence between the two sets of views (i.e., incoherent links between views of Nature and views of NOS), explicit conflicts or compromise views, or various combinations hereof (Table 4.22).

In addition, there were found to be correlations between the themes of incoherent links, and the instances of system complexity and system incoherence within the students‘ views. These results are presented in next.

Table 4.23: Number of coherent and incoherent links identified per case between views of Nature and views of NOS

Case name	Total no. of Nature-NOS links	No. of links coherent	No. of links incoherent	% Links coherent	% Links incoherent
Dan	13	13	0	100	**0**
Maya	9	9	0	100	**0**
Aaeesha	7	7	0	100	**0**
Shafia	17	16	1	94	**6**
Aamir	10	9	1	90	**10**
Reza	17	15	2	88	**12**
Raashid	15	13	2	87	**13**
Dyllan	12	10	2	83	**17**
Gideon	19	15	4	79	**21**
Samuel	13	10	3	77	**23**
Victoria	8	6	2	75	**25**
Yamina	11	8	3	73	**27**
Shanon	18	13	5	72	**28**
Brian	28	20	8	71	**29**

Relationship between themes of incoherent links and instances of system complexity/incoherence

On the one hand, the various coherence links that were established between the students' NOS views and their views of Nature were grouped according to 15 emergent themes. Nine of the themes contained incoherent links (Table 4.16, page 183). On the other hand, various instances of system complexity and system incoherence were found within the students' views of NOS and within their views of Nature (page 130 and page 162). Careful analysis of the themes of the incoherent links and the instances of system complexity/incoherence revealed similarities between them, as presented in Table 4.24.

For example, there were incoherent links relating to the theme *Predicting Nature* (Table 4.16, page 183), and there were instances of system complexity with the students' epistemological worldview descriptions concerning the extent to which future events in Nature can be predicted (page 165). A second example involves incoherent links relating to the theme *Facts & truth*, which concerned finding facts, the correct answer or the truth about the natural world (Table 4.16, page 183). These incoherent links relating to *Facts & truth* were related to instances of system incoherence and system complexity within students' epistemological worldview statements, concerning how much of Nature we can know (page 164). Furthermore, within students' views about NOS there was an instance of system incoherence regarding

Table 4.24: Summary of correlations between themes of coherent and incoherent links, and instances of system complexity and system incoherence within views of NOS and views of the natural world

Theme label	% Links incoherent	Synopsis of contents	Correlation with instances of system complexity / system incoherence within views of NOS and/or Nature	Contents that correlate
Predicting Nature	32	Making predictions about future events	NATURE: Epistemological	To what extent can natural events/phenomena be predicted and prevented?
Uncertain, doubt, mistakes	41	Making mistakes and mis-information, Uncertainty, Doubt/mistrust	NATURE: Epistemological	How much remains undiscovered and unknown/unexplained?
			NOS: Empirical evidence vs. Disbelief/doubt	Evidence, credibility and reliability vs. science as a human endeavour (theory-laden, socially- and culturally-embedded, tentative, etc.).
Science vs. religion	53	Believing in God or science	NATURE: Epistemological	Different domains of knowledge (e.g., scientific accounts vs. religions beliefs).
			NATURE: Ontological	Making sense of naturalistic and super-naturalistic explanations of how Earth was formed as well as explanations of purposes and processes in Nature.
			NOS: Who can know things	Different worldviews exist, and alternative knowledge frameworks.
Find out & learn	8	Finding out, studying, and learning about Nature	NATURE: Epistemological	How much of Nature can we know? How do we find out things about Nature?
			NATURE: Ontological	Who can know about Nature: people or God?

Table 4.24 (cont...)

Theme label	% Links incoherent	Synopsis of contents	Correlation with instances of system complexity / system incoherence within views of NOS and/or Nature	Contents that correlate
Facts & truth	8	Finding the truth, the correct answer, the facts	NATURE: Epistemological	How much of Nature can we know?
			NOS: What do scientists know?	One answer vs. disagreements amongst scientists.
			NOS: Facts vs. imagination/ estimation	What is meant by a scientific —fact”? Interaction between empirical evidence and imagination/speculation.
Search, explore, observe	9	Searching for evidence, exploring places, seeing things in Nature	NATURE: Epistemological	How we find out things about the natural world (e.g., everyday observations vs. formal research studies).
			NOS: Where and how scientists work	How exactly do scientists work? Diverse fields of scientific study and individual ways of working.
Unknown	10	Insufficient information, Unknown and undiscovered, Scientists disagree	NATURE: Epistemological	How much remains undiscovered and unknown/unexplained?
			NOS: What do scientists know?	Disagreements amongst scientists and if/how they are resolved.
			NOS: Facts vs. imagination/ estimation	What it means to use imagination/creativity in science, how this compares to fiction.
Change	20	Changes in Nature, Changes in scientific knowledge	NOS: Empirical evidence vs. disbelief/ doubt	Reliability of scientific knowledge vs. theory-laden and tentative aspects of NOS.
Invent & develop	9	Inventing/ developing things, to improve our world	NATURE: Epistemological	Relationship between increased knowledge of Nature, enjoyment/appreciation of Nature, and using/protecting the natural environment.
			NATURE: Status	Sustainable use of resources (Nature as a resource vs. need to conserve and protect Nature).
			NOS: Aim/purpose of science	Science-technology-society issues, relationship between science and technology.

disagreements arising amongst scientists vis-a-vis the existence of a single final answer in science (page 131). There were also instances of system complexity within students‘ NOS views, concerning what is meant by a scientific fact, and the interplay between empirical evidence, estimation/speculation and the role of imagination in the development of scientific knowledge (page 135). As such, the coherence *between* students‘ views of the natural world and their views of NOS, was related to the coherence *within* each of these two domains.

To recap the results concerning coherence, a number of principles of explanatory coherence theory were employed in conducting systematic and structured analyses of coherence between the students‘ views of the natural world and their views of NOS. A large number of links, both coherent and incoherent, were identified between the students‘ worldview and NOS responses, which were reduced into 15 themes (within five clusters). Links belonging to themes clustered as *Sure knowledge* were mostly coherent, whilst themes concerning *Unsure knowledge* contained a relatively low proportion of coherent links. Cross-case analyses of the various coherent and incoherent links results yielded some generalised insights into the relationship between the students‘ descriptions of the natural world and their views of NOS, and drew attention to the complex relationship between worldview and NOS. However, further, in-depth analyses of particular links between views of Nature and views of NOS links (i.e., coherent links with naive NOS views and incoherent links with informed NOS views) highlighted issues that could inform how science teachers can help their students to develop a more informed understanding of NOS. Moreover, it was found that incoherent links between the students‘ views of Nature and of NOS were related to instances of system complexity and system incoherence between the two domains. On the whole, due to the instances of system complexity and system incoherence within the students‘ worldview descriptions and/or NOS views, incoherent links between these two domains, as well as explicit conflicts and compromise views articulated by the students, it was considered that the Grade Six students‘ views were not coherent overall.

Chapter summary

The results presented in this chapter pertained to each of the three components of the study, namely, the students‘ views of NOS, their views of the natural world, and the coherence of these two domains. In regard to the students‘ views of NOS, a unique NOS profile was compiled for each case. The students‘ NOS responses were found to be rich and represented a range of views about each of the five NOS aspects investigated (i.e., tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative/creative). However, the students' NOS understandings did not develop uniformly for all five aspects. A number of instances of system complexity and system incoherence were identified within the students' NOS views, and these included descriptions of border-crossing experiences (e.g., conflicts between what was taught in school science as opposed to knowledge presented at home).

In regard to the students' views of the natural world, an individual worldview profile was compiled for each case. The students defined Nature as being distinct from people and/or human activity. Furthermore, the students described diverse and complex views regarding each of the four worldview descriptions investigated (i.e., epistemological, ontological, emotional and status descriptions). A number of instances of system complexity and system incoherence were identified within the students' views of Nature, and these included descriptions of border-crossing experiences (e.g., explicit conflicts between personal religious views and science).

Regarding coherence, the students' definitions of Nature were coherent with and their descriptions of the kinds of work that scientists do and the aims/purpose of science. Links (both coherent and incoherent) were identified between students' views relating to the four worldview descriptions and the five NOS. Cross-case analyses of these various coherent and incoherent links yielded some general insights into the relationship between the students' views of NOS and their descriptions of the natural world. Further in-depth analyses followed, which involved the examination of the coherent links between students' naive views of NOS and their views of Nature, as well as examining the incoherent links between students' informed NOS views and their views of Nature. A number of issues arose from these particular links. Overall, due to the instances of internal complexity and incoherence within the students' NOS views and within their descriptions of Nature, the incoherent links between these two domains, and the students' descriptions of explicit conflicts and compromise views, it was concluded that the Grade Six students' views were not coherent overall.

The results presented in all three parts of this chapter are reviewed and discussed in the Discussion Chapter, which follows next.

Chapter Five
DISCUSSION

One of the major goals of science education is that students become scientifically literate. Scientific literacy includes holding an informed understanding of the nature of science, that is, of science as a way of knowing, including the beliefs and values inherent in science and the way in which scientific knowledge is developed. Students' NOS views have been found to be typically naive, hence the need to determine the factors influencing their NOS views and, subsequently, to determine ways in which students' levels of NOS understanding can be improved. There are a number of factors influencing a person's NOS views, and one such factor is a person's worldview. Worldview can be described as a set of beliefs constituting a person's way of looking at and understanding the world. Students' pre-existing ideas and beliefs provide the framework through which they interpret new ideas that are presented to them in the classroom. However, the exact relationship between worldviews and NOS views is currently unknown (Chapter 2, page 19), and therefore constitutes an area of pertinent and timeous research. Of particular interest in science education are students' views of the natural world, as Nature is the domain in which science operates. Relatively little is known about the NOS views of elementary school students. Moreover, little NOS research in general has been conducted in South Africa.

The aim of the present study was therefore to explore the relationship between South African Grade Six students' views of the natural world and their views of NOS. Due to the paucity of research that has been conducted in this particular area, and given the complexity of investigating the relationship between students' views of the natural world and of NOS, an exploratory methodology was employed, whereby principles of explanatory coherence were applied in analysing the coherence within and between the students' views (Chapter 2, page 49). As such, the research questions in this study concerned the students' conceptualisations of Nature, their understanding about NOS, and the coherence between their views of these two domains. Specifically, the present study was designed to answer the following main research question: *How do South African Grade Six students' views of the nature of science (NOS) cohere with their views of the natural world?* This main research question was addressed by answering sub-questions relating to each of the three parts, as detailed below.

1. *What views of NOS do the Grade Six students hold, and what are students' levels of understanding about each NOS aspect?*

The students' views of NOS were studied by eliciting their views of the nature of scientists' work and the role/purpose of science, and more specifically, by analysing the students' levels of understanding about five particular aspects of NOS (i.e., tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative/creative)—in order to be able to compare their individual NOS profiles. The internal coherence of the students' NOS views was also examined.

2. *What views of the natural world do the Grade Six students hold?*

The students' views of Nature were studied by analysing their definitions of Nature, and their views of the natural world relating to four particular worldview descriptions (epistemological, ontological, emotional, and status)—in order to conduct a comparison of students' individual worldview profiles. The internal coherence of the students' views of the natural world was also examined.

3. *To what extent do the students' views of NOS and their views of the natural world cohere with one another?*

Coherence between the students' views of NOS and their views of Nature was explored by identifying coherent and incoherent links between their views of each domain, examining the relationship between these various links and the students' levels of understanding about NOS, and then finally, determining the overall coherence of the students' views.

Due to the exploratory nature of this study, the research design was qualitative, employing a multiple case study approach that enabled in-depth analyses of the students' views. A purposive strategy was used in selecting the cases, in order to maximise diversity amongst participants' views of the natural world whilst taking into account some of the other possible variables that might affect the students' NOS views (e.g., age, gender, language, nationality, religion, social class, academic ability level, NOS teaching at the school) (Chapter 3, page 57). Details of each school's religious policy (where religion was used as a marker of cultural diversity) and the nature of science teaching at the school were obtained by means of conducting semi-structured interviews with school principals, science teachers and the HOD of science at each participating school (Chapter 3, page 63 and page 64). Background information for each case was collected by administering individual, written questionnaires entitled, *Who am I?* (Chapter 3, page 67). The students' NOS views were elicited by means of individual, written questionnaires (*VNOS-rs*) incorporating an immediate review of each student's answers. Individual, semi-structured follow-up interviews were employed as a means of clarifying students‘ responses and verifying the initial analyses of the data (Chapter 3, page 77). Students‘ descriptions of the natural world were elicited by means of individual, structured, activity-based worldview interviews, based on Cobern‘s (1991, 2000b) methodology for studying students‘ conceptualisations of Nature (Chapter 3, page 80).

The students‘ views of NOS were analysed using an analytic framework which described the possible contents of informed, developing and naive views about each of the five target NOS aspects. This analytic framework was compiled from various international reform and curriculum documents for NOS (Chapter 3, page 78). The students‘ views of the natural world were analysed by assigning codes to portions of worldview interview transcripts, and then creating a concept map and a worldview narrative (Nature story) depicting each student‘s description of the natural world (Chapter 3, page 92). Finally, principles of explanatory coherence were applied in analysing the coherence within and between the students‘ descriptions of the natural world and their views about NOS (Chapter 3, page 97).

Limitations and methodological features of the study

In this section, a limitation of the present study is discussed, which pertains to the collection of data concerning the Grade Six students‘ academic ability levels. This is followed by a description of three methodological features of the study. These features are related to the selection of participants, the design of the worldview interview, and the discussion of results in relation to existing science education research literature.

A limitation of the present study relates to the data concerning the students‘ academic ability levels. During the data collection process, the teachers at each school were asked to indicate whether each of the participating students was a top, middle or bottom academic ability student (Chapter 3, page 58). Unfortunately this broad categorisation proved to be problematic later, for the following reasons: (1) there was no indication of what might constitute a student of top, middle, or bottom academic ability level (such as, for example, results from a report card that would be reflected as a percentage value); (2) some teachers created their own additional sub-categories, that is, they described individuals as top-middle or bottom-middle ability students—again, it is unclear what these additional categories mean; (3) teachers categorised each student relative to the rest of the students in their class. Consequently, it is difficult to make a fair comparison of students in different classes and at different schools. Due to the questionable reliability of these data, it was not possible to comment on the relationship between students‘

academic ability levels and their views of Nature, or on the relationship between students' academic ability levels and their levels of understanding about NOS.

Regarding the selection of Grade Six students to be studied, multiple cases were purposively chosen, in order to maximise variation amongst the students' worldviews whilst controlling for a number of variables—besides worldview—that might influence their NOS views. Although cultural factors were taken into account, the present study was not designed as a cross-cultural comparison, neither was it intended as a study of religion. However, as previously explained (Chapter 2, page 37; Chapter 3, page 57), religion was used as a marker of cultural diversity in selecting respondents who held a variety of different views of the natural world (a worldview component). The impact of this case selection strategy needs to be considered. Worldviews typically concern questions such as: "What sorts of things exist in the universe? Is the universe created by an intelligent being?...What is the structure of reality?...How should we live our lives?...Is there a purpose to life in general, or to the universe as a whole?...[and] How should we go about answering these questions?" (Irzik & Nola, 2009:730-731). Answers to these questions might be sought in various knowledge frameworks, including religion. Religion can be regarded as playing an important role in shaping individuals' worldviews (Cobern, 2000a; de Wet, 2000; Prozesky, 1991), and the results of the present study show that, to some extent, religion did influence the students' descriptions of the natural world. This was apparent in their super-naturalistic and strongly super-naturalistic worldview responses. However, there were also cases in which students described naturalistic and strongly naturalistic views of the natural world. Furthermore, in a number of cases, multiple individuals who self-identified as belonging to a particular religious group described diverse views about Nature (Chapter 4, page 151). The worldview profiles of the students in this study were therefore not a function of their particular religious affiliations. Thus, this particular strategy for selecting respondents (i.e., using religion as a cultural marker of diversity) did not threaten the validity of the results obtained.

A second methodological feature of the present study concerns the design of the worldview interview. Structured interviews were conducted with the students in order to elicit detailed descriptions about Nature from them (Chapter 3, page 80). Although it is acknowledged that a structured interview schedule might constrain participants' responses, the interview design employed in the present study had a number of benefits. To begin with the use of various activities and elicitation devices helped to concretise the topic of Nature for the students, and to keep their attention focussed. Moreover, the structure of the interview enabled the researcher to employ the same interview procedure for all participants, which enabled the analysis of cross-case comparisons later. Meanwhile, the think-aloud approach provided open-ended opportunities for the students to provide personal illustrations and explanations, so that variations amongst individuals could be recorded. Furthermore, all this was possible whilst also taking into account the time-constraints inherent in school teaching timetables.

A third feature of the study is related to the discussion of results in the final chapter of the thesis (i.e., Chapter 5). In the present study, a novel analytic approach was employed in exploring coherence between the Grade Six students' views of the natural world and their views of NOS. This new analytic approach involved the application of principles of explanatory coherence (Chapter 3, page 97). However, due to the lack of existing work of this nature (Chapter 2, page 51), it was difficult to discuss the present findings in relation to the results of previous studies. Consequently, where possible, components of the results from the present study are discussed in relation to particular aspects of the findings reported in the existing research literature.

In the previous chapter, results were presented regarding the students' NOS views, their views of the natural world, and coherence between the two domains (Figure 5.1 presents a diagrammatic overview of these findings). These results are discussed in this chapter, and a number of implications and recommendations are described pertaining to both science teaching and future science education research. The discussion is structured according to the three sets of sub-questions, which relate to the students' views of NOS, their views of the natural world, and coherence of the two sets of views.

Part 1: Views of the nature of science (NOS)

In this section, the results concerning the students' NOS views are discussed. This is done by first looking at the students' views about the methods and aims of science, and then discussing the levels of NOS understanding that the students described. Individuals' NOS profiles are considered third, followed by a discussion of the richness and range of the students' various NOS descriptions. Finally, there is an examination of coherence within the students' NOS views.

The work of scientists and the role/purpose of science

Students' general images of science and scientists can help us to better understand their epistemological views of science (i.e., their NOS views) (Kan et al., 2004; Schibeci, 2006). Furthermore, it was considered that the students' descriptions of the role/purpose of science,

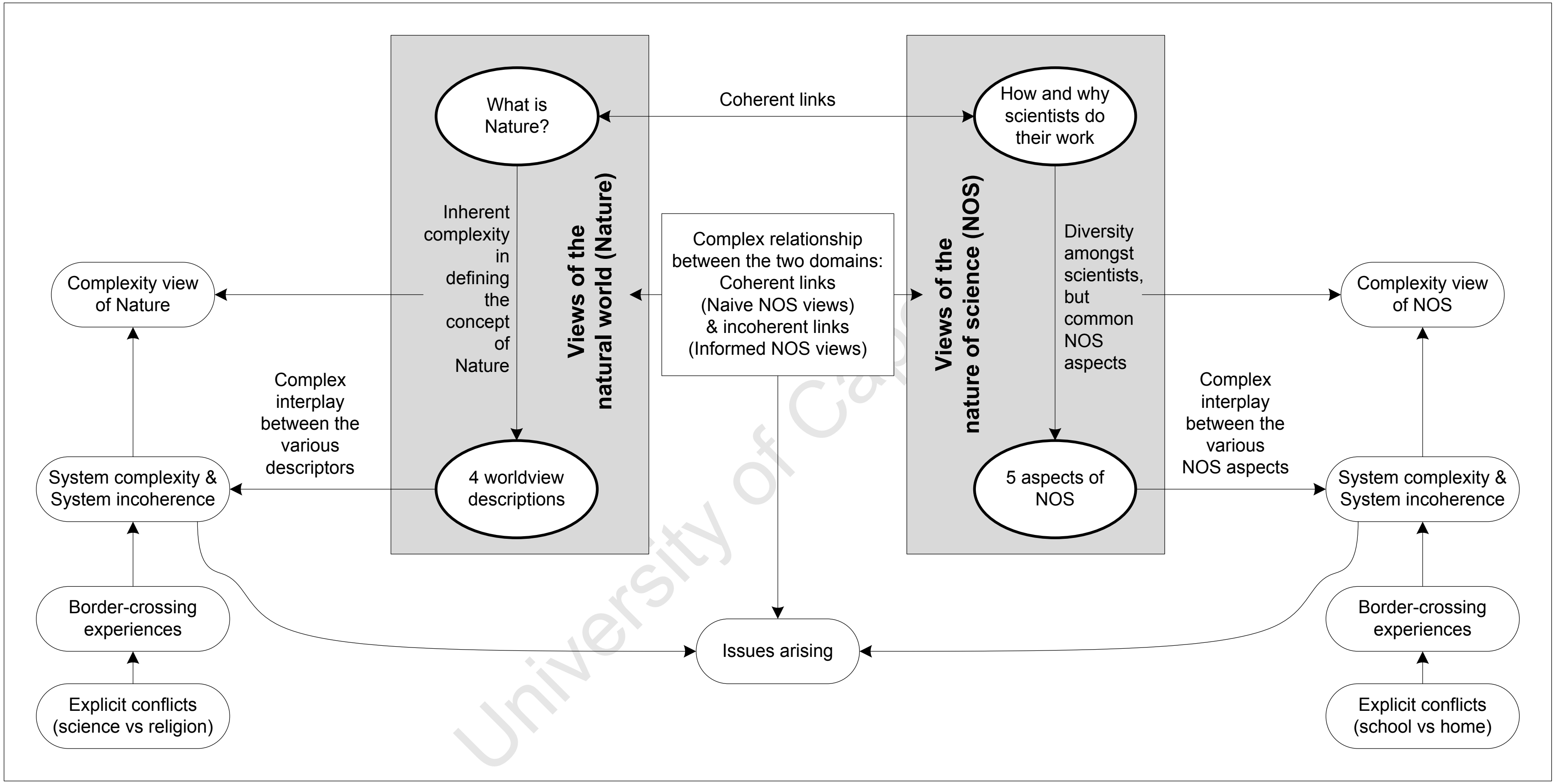


Figure 5.1: Overview of the findings of the present study, regarding the students' views of NOS, their views of the natural world, and the coherence of these two domains

and the kinds of work that scientists do, might present links with their views of the natural world (Chapter 4, page 106). Therefore, although these views were not the focus of the NOS data in the present study—the focus was primarily on students‘ views of the tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative/creative aspects of NOS—the results concerning the students‘ views of the methods and aims of science are discussed here. A discussion of the coherence between students‘ views of the methods and aims of science, and their worldview statements, is presented in Part 3 of this chapter (i.e., Coherence) (page 180).

Views of the methods and aims of science

The results show that the students recognised that scientists are involved in a variety of different kinds of work. However, their views of scientists‘ work was limited to scientists studying plants, animals and the environment, the weather, outer space, diseases, and historical artefacts (Chapter 4, page 106). Yet science includes a wider range of fields of study, such as, for example, physics, in/organic chemistry, genetics, anthropology, criminology, computer science, and so forth. Moreover, the students only described scientists‘ work in terms of conducting experiments, working with chemicals and technology, discovering things and creating new inventions (Chapter 4, page 106). Overall, therefore, the students described limited views of the kinds of work that scientists do. This result supports the finding of a recent study involving mid-Western United States Sixth Graders, in which students were reported to hold a poorly developed understanding of what scientists do and, in particular, students confused scientists with engineers (Karatas et al., 2011). Similarly, an earlier study involving middle school students in the southeastern United States (i.e., Grades Six to Eight) (Lyons, Fralick, Kearns & 2009) found that students held misconceptions concerning the relationship between engineering and science. As a result of the present findings and those of previous studies concerning students‘ limited understanding of the nature of scientists‘ work, in order to help students to develop more informed NOS views, it is recommended that science teachers provide students with detailed insights into the ways in which scientists work, and alert students to the differences amongst the work of individual scientists. Discussions also need to focus on the great diversity of the various fields of science, and the possible interplay between them (e.g., the relationship between science and engineering).

The students‘ descriptions of the aim/purpose of science were more informed than their perceptions of the kinds of work that scientists do. Students identified the need for scientists to gain knowledge and understanding of, and to answer questions about, the natural world, motivated by curiosity and fascination (Chapter 4, page 108). Understanding that scientists investigate natural phenomena and explain how the world works, is considered an informed view for elementary school students (Kang et al., 2005). Furthermore, it has been found that students commonly regard scientists as being motivated by curiosity to find out about things in Nature (Hodson, 2009). In the present study, some students also identified the role of science in developments that improve our lives and the world in which we live (Chapter 4, page 109). This finding is line with previous findings (e.g., Hodson, 2009; Kang et al., 2005) that younger students, in particular, regard science as making or inventing something to improve the quality of our lives, and that scientists are motivated by a desire to make the world a better place to live in.

Diverse fields of study in science

As previously explained (Chapter 3, page 72), the students' views of NOS were elicited by means of a written *VNOS-rs* questionnaire and semi-structured follow-up interviews. With the exception of Question Five (concerning dinosaurs) and Question Six (relating to the weather), the *VNOS-rs* questionnaire comprised generic questions about scientists and about science. Particular fields of science were not specified. Even so, the students' NOS responses—specifically, their responses to the introductory questionnaire items (i.e., Question One)—included descriptions of diversity amongst scientists arising from the multiple fields of study that constitute science (Chapter 4, page 106). It therefore seems necessary to consider briefly the significance of this result as (1) a methodological issue, and (2) in terms of teaching implications.

In regard to methodology, one might question whether the students' answers would reveal a different NOS understanding if—rather than using generic questions that simply referred to *science* and *scientist*—their NOS views were probed in regard to particular types of scientists (e.g., botanists as opposed to nuclear physicists, geneticists, archaeologists, and so forth). This question has been raised previously (e.g., Leach, Millar, Ryder & Séré, 2000). Although it is recognized that the aspects of NOS typically researched (i.e., tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative/creative) are generally applicable to all fields of science, it is also acknowledged that each field of science has particular characteristics. Thus, probing respondents' NOS views by means of more context-specific questions might help to elicit a potentially fuller picture of their understanding about science. Accordingly, a possible avenue for future NOS-related research involves exploring the effect of employing question items relating to specific fields of science in eliciting respondents' views of NOS.

In regard to teaching, instruction concerning NOS at schools should take into account the different fields of study within science. That is, it is recommended that science teachers introduce specific discussions regarding the variations amongst fields of science (e.g., the subject matter studied in each field) whilst also highlighting common features of scientific knowledge (e.g., that it is empirically-based, theory-laden, and so forth). Importantly, these discussions would also draw attention to how each of the common aspects of NOS (e.g., the use of imagination and creativity) would be applied in each of the various fields of study. Furthermore, such discussions might serve to address students‘ limited understanding of the distinctions between particular sub-fields of science (e.g., archaeology, palaeontology, history, etc.), as was evident in the results obtained in the present study (Chapter 4, page 117).

Further to analyzing the students‘ views of the role/purpose of science and the nature of scientists‘ work, data were collected and analysed concerning the students‘ levels of understanding about the tentative, empirically-based, theory-laden, socially-and-culturally-embedded, and imaginative and creative aspects of NOS. These results are discussed next.

Levels of NOS understanding

It has been reported that elementary school students possess their own epistemologies of science (e.g., Conley et al., 2004), although they might hold distorted views of scientific knowledge (Kang et al., 2005). Results from NOS research over the last half century, using a wide variety of assessment instruments, have led to the conclusion that students typically do not possess adequate conceptions of the nature of science (e.g., N.G. Lederman, 2007). However, it has also been found that young students can develop rich views of science (Akerson & Donelly, 2010). Moreover, elementary students—even as early as Grade One—are able to develop an adequate understanding of particular NOS aspects with explicit and reflective NOS instruction (Akerson & Volrich, 2006; Khishfe, 2008; J.S. Lederman & Lederman, 2005b; Smith et al., 2000).

In the present study, the results show that only two of the 14 students in the study (i.e., Victoria, Shafia) held NOS views that were informed regarding all five NOS aspects. The remaining students held NOS views that comprised varying combinations of informed and/or developing and/or naive levels of understanding regarding the five NOS aspects. Eight students described NOS views that were somewhat informed or largely informed overall, whilst six students described NOS views that were naive or developing overall (Table 4.9, page 129). These findings regarding the students‘ overall levels of NOS understanding support the assertion that elementary students do possess their own epistemologies of science. However, the results of the present study reflect NOS understandings amongst students that are slightly more informed than those reported in previous NOS studies, as the students' views were not predominantly naive.

Although the students' NOS views were found to be less naive in the present study than what has been recorded elsewhere, the results showed that the students held alternative and limited understanding of particular terms they used in describing their NOS views, as is discussed next.

Alternative meanings

It is not uncommon for students to hold a limited understanding of the meanings of some of the terms used in describing NOS, such as *prove* and *fact* (Abd-El-Khalick, 2006; N.G. Lederman & O'Malley, 1990; Liu & Lederman 2002). It has also been reported that some students do not fully understand the concept of a theory (Abd-El-Khalick, 2006; Sutherland & Denick, 2002). In some cases, students have referred to *proof/prove* as finding supporting evidence (Abd-El-Khalick, 2006; Liu & Lederman, 2002) rather than the more robust meaning which indicates knowing with certainty (Khishfe & Abd-El-Khalick, 2002). Similarly, *fact* has been described as something observable and concrete (Liu & Lederman 2002). Students tend to view *theory* as a conjecture or an educated guess, and they tend to think that a theory is an uncertain and unconfirmed opinion which becomes a fact after scientists prove it (Kang et al., 2005). Students have also typically been found to hold naive/everyday definitions of *scientific imagination and creativity*, where their understanding was more closely related to artistic creativity, as opposed to creativity for developing scientific knowledge and claims (Abd-El-Khalick, 2006; Akerson & Abd-El-Khalick, 2005; Akerson & Donelly, 2010; Akerson & Hanuscin, 2007). For example, in describing how scientists use their imagination and creativity, students have reportedly referred to the ability to make one's scientific product/experiment attractive in presenting the work to others (Khishfe & Abd-El-Khalick, 2002). Indeed, in the present study, Reza described such a view when he explained that scientists use their creativity only when deciding how to present their work to other people (for example, adding a border and pictures) (Appendix 4.1, Table-A4.1-11 [page 371]). Maya also assigned an alternative meaning to the word *imagination* when she likened the use of imagination to guessing (Chapter 4, page 121). The analytic codes assigned to naive responses regarding the role of imagination and creativity in science provide further evidence of alternative meaning students attached to these terms (e.g., where imagination was regarded as fiction, or in relation to attempts to remember previously learnt facts) (Appendix 4.1, Table-A4.1-11 [page 371]).

In addition to the alternative meanings discussed above, it was found that some students held a limited—and in some cases, alternative—understanding of some of the other terms they used (e.g., myths, theories, facts and opinions, and guesses) as well as having a limited understanding about the subject-matter studied in science (e.g., archaeologists, history vs. science) (Chapter 4, page 117). These alternative and limited understandings hold methodological implications for NOS researchers when eliciting students' NOS views and correctly analysing their responses, as well as holding implications for science teachers in regard to improving students' understanding of particular NOS concepts and NOS-related issues.

Methodological implications: Eliciting and analysing respondents' views

In the present study, the students' NOS views were initially elicited by means of written questionnaire responses. Thereafter, in order to achieve greater clarity of the meanings that individuals attached to particular statements they made, the students' understanding and use of particular terms were probed further during semi-structured follow-up interviews (Chapter 3, pages 76-7). It was during this follow-up interview procedure that some students' limited/alternative understanding became apparent and could be probed further. Certainly, there exists a need to ask students to explicate the meanings of some of the terms they use in describing their NOS views (such as imagination and creativity, proof and evidence, and fact) and to illustrate their explanations with examples (Khishfe & Abd-El-Khalick, 2002; Liu & Lederman, 2002). This is necessary in order to assess accurately respondents' understanding and views of NOS (Abd-El-Khalick, 2006). Accordingly—and in line with previously published recommendations (Cohen et al., 2007; N.G. Lederman, 2007; N.G. Lederman & O'Malley, 1990)—it is strongly recommended that NOS researchers supplement and expand respondents' written questionnaire responses with follow-up interviews when eliciting their views of NOS. This point is discussed further in a later section (page 224).

Implications for science teachers: Teaching NOS concepts

Students' limited and/or alternative understanding of NOS-related terminology hold implications for science teaching. That is, when teaching students about NOS-related issues, teachers need to make a point of clarifying and explaining what is meant by terms such as *theory* and *fact*. There is also a need to clarify the meanings of terms normally used in everyday language, when they are used in the context of science (for example, the role of imagination and creativity pertaining to science as opposed to composing a piece of creative writing in a language course). This is because, for example, when students hold more informed scientific definitions of the terms *imagination* and *creativity*, they are more likely to hold more informed views of how scientists use imagination and creativity in their work (Akerson & Abd-El-Khalick, 2005; Akerson & Hanuscin, 2007).

In addition to holding limited/alternative understanding of terms such as *imagination*, *theory*, *fact*, and so on, in the present study it was found that some students held a limited understanding of archaeologists whilst others did not clearly distinguish the study of science from that of history (Chapter 4, page 118). It is therefore suggested that when teaching students about NOS, science teachers need to clarify what kinds of subject-matter are studied in science, and how science is different to other fields of study. Also, in discussing the varieties of types of work that scientists do, it is recommended that science teachers define the names given to different scientists (e.g., archaeologist, botanist, geologist, etc.). In turn, students might develop a more informed understanding not only of the tentative, empirically-based, theory-laden, socially-and-culturally-embedded, and imaginative and creative aspects of NOS, but also of what the various fields of study in science are concerned with, and how science differs from other fields of study. It is important that students hold an accurate understanding of such concepts in the aim of becoming scientifically literate.

The above discussion has focussed on the students' overall levels of NOS understanding, and on various limited/alternative meanings that individuals assigned to particular terms they used in describing their NOS views. What follows is a comparison of students' individual NOS profiles, which reflected individuals' levels of understanding about each of the five target NOS aspects.

Individual NOS profiles

In the present study, a NOS profile was compiled for each case, which presented a synopsis of the student's view concerning each of the five target NOS aspects (i.e., tentative, empirically-based, theory-laden, socially- and culturally-embedded, and imaginative/creative aspects of NOS) (Chapter 4, page 126). Compiling NOS profiles is a useful means of encapsulating the essence of individuals' NOS views, but constitutes a relatively novel approach for presenting and comparing the NOS results of multiple cases (Hodson, 2009).

In a recent South African study of first-year physics students' ideas about measurement, four *generalised* NOS profiles were identified amongst the students' NOS views (Ibrahim et al., 2009). These generalised profiles—although not representative of all participants—were developed in order to compare the four profiles of students' NOS views with two types of views on measurement. In the present study, *individual* NOS profiles were created as an initial means of comparing the students' NOS views with their views of the natural world. The students' individual NOS profiles revealed the uniqueness of the students' NOS views, and highlighted the diversity of NOS views represented in the group of cases (Chapter 4, page 126). It was therefore not feasible to attempt to develop a limited set of generalised profiles to represent the group of cases. Moreover, in order to conduct in-depth analyses of coherence of the relationships between particular statements about NOS and about Nature, describing students' NOS views merely in terms of one of a limited set of generalised profiles would have been inadequate. It was also considered that greater insight would be gained from reporting on ranges of views on various levels of understanding for each NOS aspect, and identifying students' naive views that needed to be addressed.

As already mentioned (Chapter 4, page 126), great diversity was found amongst the NOS views of the 14 cases analysed in the present study. A comparison of individual NOS profiles revealed that the students at any particular school did not necessarily hold similar views of NOS, notwithstanding the fact that NOS concepts were not taught explicitly at any of the participating schools. Moreover, no obvious relation was found between the students' worldview profiles and their NOS profiles (Chapter 4, page 178). Besides science teaching and individuals' worldviews (incorporating religious views), possible factors influencing individuals' NOS views include cultural variables such as age, gender, language, nationality and social class (i.e., socio-economic status) (Anderson et al., 2001; Case & Deaton, 1999; Hodson, 2009; Liu & Lederman, 2002; Sutherland & Dennick, 2002; N.G. Lederman, 2007). However, no obvious relationship was found between gender and NOS views, and the other variables were controlled by means of employing a purposive strategy in selecting the 14 cases (Chapter 3, page 57). The relationship between the students' academic ability levels and their levels of NOS understanding could not be explored due to limitations of the data (Chapter 5, page 213). The impact of additional factors such as exposure to media (e.g., television, Internet) was not measured in this study. Indeed, this study was not designed to identify the factors influencing students' NOS views, but rather to explore the relationship between the students' views of the natural world and their ideas about NOS (Chapter 1, page 7). As such, the NOS results obtained here cannot provide further insights into the reasons for the great diversity of NOS views represented by the students studied.

However, the strategy of compiling individual NOS profiles holds implications for science teachers. As previously mentioned, individual NOS profiles serve as a useful means of presenting a synopsis of a student's NOS view, by indicating particular levels of understanding that are currently held about particular NOS aspects. As such, individual NOS profiles could be employed by teachers as a valuable formative assessment tool in their attempts to improve students' levels of NOS understanding (Allchin, 2011). The development and classroom application of students' NOS profiles presents a possible avenue for further research.

Further to a comparison of individual students' NOS profiles, the results of the present study reported the richness and range of students' NOS views. These results are discussed next.

Contents of the students' views relating to the various NOS aspects

The students' NOS views were found to be rich, and their responses represented a range of views relating to various levels of understanding about each of the five NOS aspects. In a number of cases, references were made to mistrust and doubt in science. Moreover, analysis of the students' NOS responses highlighted the inherent complexity of concepts relating to the various aspects of NOS. These findings are discussed in more detail below.

NOS views are rich

Data concerning each student's NOS views were collected by means of individual, written questionnaire responses (*VNOS-rs*), plus individual, semi-structured follow-up interviews. The follow-up interviews provided opportunities to probe respondents further regarding their understanding of NOS, by clarifying some of the earlier statements that had been recorded and by providing examples to illustrate their views (Chapter 3, pages 76-7). The use of follow-up interviews to supplement written questionnaire responses has been advocated by NOS researchers (e.g., N.G. Lederman, 2007).

Notably, in the present study, an additional feedback opportunity was created: Immediately after each student completed their initial *VNOS-rs* questionnaire, the researcher reviewed their written responses with them. The researcher recorded the students' oral feedback verbatim in writing (Chapter 3, page 75). This additional data collection strategy served multiple purposes, namely, to ensure that all questionnaire items had been completed adequately, to provide opportunities for respondents to clarify unclear responses, and to probe the students' ideas further whilst their initial written responses were still fresh in their minds. The immediate-review process further served to overcome a possible methodological limitation of relying solely on written statements from the students, where there might be cases that some of the 11-12 year-olds articulated more comprehensive answers in an oral mode. Moreover, clarifying and expanding the students' initial written responses immediately thereafter, greatly facilitated the initial analysis of their NOS views. Consequently, in order to elicit clear, rich and detailed descriptions of students‘ NOS views, it is recommended that researchers not only employ follow-up interviews to supplement questionnaire answers, but that an initial follow-up opportunity also be created for the immediate review of students‘ written responses.

In analysing the students‘ NOS views in the present study, it was found that particular NOS statements were sometimes related to multiple NOS aspects, which concurs with the findings of previous NOS studies (e.g., Khishfe & Abd-El-Khalick, 2002). In the present study, data analyses also revealed that the students‘ NOS statements were sometimes related to multiple levels of understanding. This result is in agreement with Khishfe‘s (2008) finding that in responding to different items on a questionnaire, students described views relating to different levels of understanding. Consequently, in the present study, when assessing an individual‘s level of understanding pertaining to a particular NOS aspect, all of the statements relating to that NOS aspect were considered together. This approach was deemed to reflect a more true assessment of the student‘s level of understanding than analysing each NOS statement in isolation, as recommended elsewhere (Khishfe & Abd-El-Khalick, 2002). Consequently, in order to avoid making limited or inaccurate assessments of individuals‘ NOS understanding (i.e., by considering their various NOS statements in isolation from one another), it is recommended that NOS researchers adopt a holistic approach in the analysis of such data.

Range of students’ views about NOS

The results of the present study show that the students articulated a range of views relating to informed, developing and naive understanding of each of the five target NOS aspects. Analysis of these views revealed some commonalities amongst the NOS responses and, consequently, themes of NOS responses were identified (Chapter 4, page 109). For example, students‘ naive views of the tentative nature of science, included views that scientists do not make mistakes and that science facts do not change; and if the facts did change, then scientists would not tell people as it would create confusion (Table 4.13, page 156). The emergence of various themes of NOS responses highlighted the wide range of views described by the students. Furthermore, the identification of these themes holds implications for NOS teachers and researchers alike. It is recommended that science teachers draw on the themes of NOS responses in order to address specific concepts (misconceptions) when teaching students about NOS, for example, to discuss mistrust/doubt in science (this particular issue is discussed next). Science education researchers can use the themes that were identified amongst the students‘ NOS responses in the present study as a reference point for documenting the range of NOS views that students hold, and then to expand the set of themes where necessary during future NOS studies.

Mistrust in science

Mistrust and doubt in science was an issue that emerged across a number of the NOS themes such as, for example, in students' views concerning the empirically-based aspect of NOS (i.e., *Doubt in science* [developing], *Mis-information*, *Dishonest* [naive]) (Appendix 4.1, Table A4.1-2 [page 354] and Table A4.1-3 [page 355]) and in students' views concerning the theory-laden aspect of NOS (*Uncertain* [informed], *I don't believe* [naive],) (Appendix 4.1, Table A4.1-4 [page 357] and Table A4.1-6 [pages 362-3]). Some students expressed doubt and uncertainty regarding what scientists tell us (e.g., Shanon, Shafia, Brian) (Appendix 4.1, Table A4.1-2 [page 354] and Table A4.1-6 [pages 362-3]), whilst others said that scientists tell us incorrect information (e.g., Dyllan, Maya, Shanon) (Appendix 4.1, Table A4.1-3 [page 351]). In some cases, students held the view that scientists cannot be trusted because they are corrupt and dishonest people who are trying to trick us (e.g., Brian, Dyllan, Shanon, Yamina) in order to achieve glory and personal fame (e.g., Brian, Dan, Raashid) (Appendix 4.1, Table A4.1-3 [page 355] and Table A4.1-8 [page 367]). One student's reference to mistrust concerned scientists not trusting each other and therefore not working together (e.g., Brian) (Appendix 4.1, Table A4.1-8 [page 367]). In addition to issues relating to mistrust and doubt in scientists, students raised issues concerning whom to believe. Although some students described a need to believe scientists (e.g., Aamir, Brian) others said they did not believe what scientists tell us (e.g., Dyllan) and still others said we can believe some scientists but not others (e.g., Brian, Maya, Victoria). There were also students who described difficulties in having to choose between scientific explanations and their religious beliefs (e.g., Brian, Dyllan, Gideon, Samuel, Shanon, Shafia, Victoria) (Chapter 4, page 194).

It is beyond the scope of the present study to determine the sources of students' views (Chapter 1, page 7) about mistrust and doubt in science, and uncertainty as to whom to believe, although this presents a possible topic for future study. Nonetheless, these results indicate that there is a need for science teachers to dispel myths about science that are presented in, for example, popular media (e.g., movies and cartoons about corrupt scientists). Teaching about NOS needs to emphasise intellectual honesty as an essential scientific habit of mind, and how scientists work together (i.e., subjective, and socially- and culturally-embedded aspects of NOS). There is also a need for science teachers to explain to students how the various aspects of NOS work together (for example, how scientific knowledge can be simultaneously tentative and reliable, and how scientific knowledge is empirically-based and yet also involves the use of human imagination and the development of theoretical explanations). This inherent complexity of NOS is considered in the next section. Furthermore, as discussed later (page 242-3), there is a need to address issues relating to differences between scientific and religious explanations of the natural world.

Inherent complexity of concepts relating to the five aspects of NOS

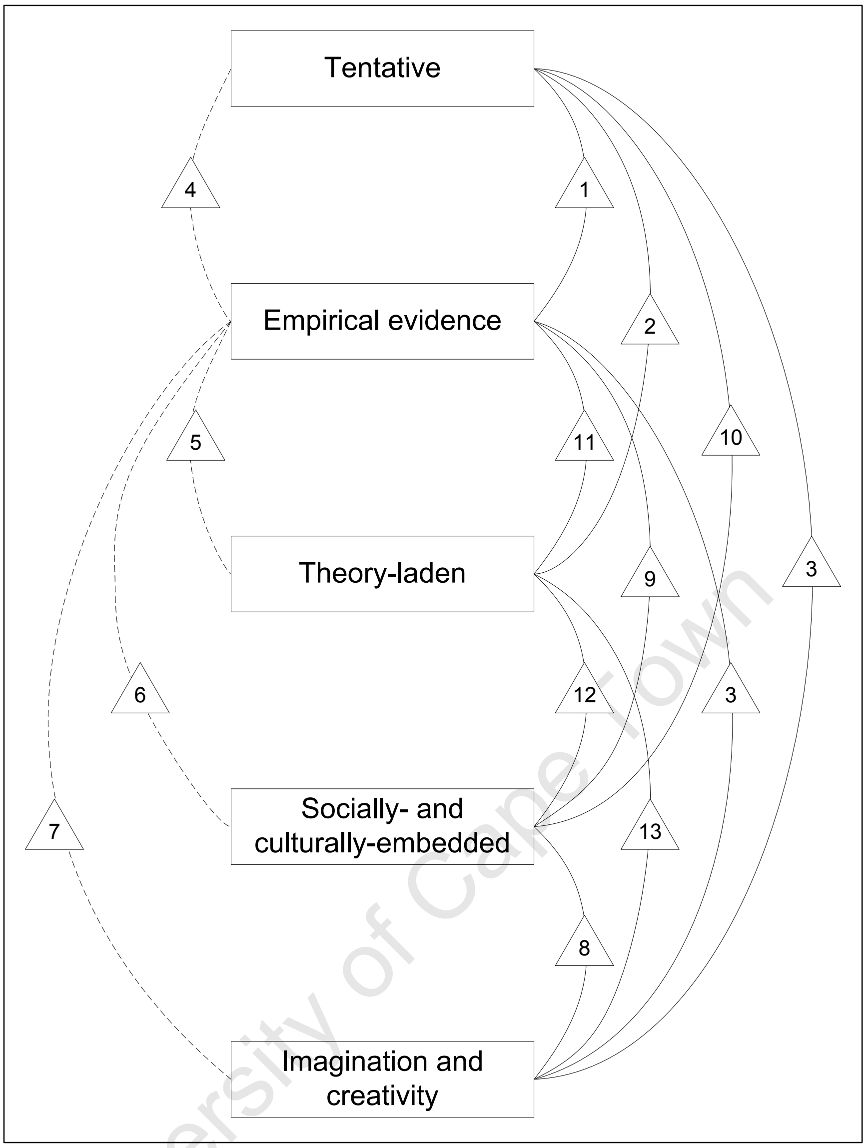
Results from the present study show that the students‘ levels of understanding varied with regard to the five different aspects of NOS. In only two cases (Shafia and Victoria) were individuals‘ levels of understanding the same for all NOS aspects—these two students held an informed understanding regarding all five NOS aspects. In the remaining 12 cases, students‘ NOS views typically comprised views that were more informed for some aspects and less informed for other aspects (Table 4.9 [page 129]). Therefore, the students‘ understanding pertaining to each of the five target NOS aspects did not develop uniformly. This result supports findings reported in other studies (e.g., Abd-El-Khalick, 2006; Akerson et al., 2000; Khishfe, 2008; Khishfe & Abd-El-Khalick, 2002; Liu & Lederman, 2002).

Overall results show that the students held the most informed understanding of the empirically-based aspect of NOS. Their views regarding the tentative, socially- and culturally-embedded, and imaginative and creative aspects of NOS were less informed. The students held the least informed understanding of the theory-laden aspect of NOS (Chapter 4, page 128). One possible explanation for this inconsistency amongst the students‘ levels of understanding about each of the various NOS aspects, is that some NOS aspects were grasped more readily than others. However, there remain questions concerning which NOS ideas are most accessible to students of various ages and grade levels (Akerson & Volrich, 2006). For example, in some studies students held informed views regarding the empirically-based and tentative aspects of NOS but had difficulty understanding the role of imagination/creativity in science (Khishfe et al., 2002). In other studies, students held more informed views of the tentative, empirical and creative/imaginative aspects, whilst their understanding of the distinction between observation and inference remained largely naive (Khishfe, 2008). In still further studies, the theory-laden and subjective aspect of NOS seemed to be the most difficult for students (Akerson & Donelly, 2010). Thus, some scholars (e.g., Kang et al., 2005) consider that inconsistencies of students‘ levels of understanding across multiple aspects of NOS could perhaps be because students compartmentalise their NOS views, or perhaps because students‘ NOS views are not yet fully formed. However, these inconsistent levels of NOS understanding might also be related to the inherent complexity of NOS. This assertion is discussed in more detail below.

In addition to the students‘ levels of understanding being inconsistent across the various aspects of NOS, a number of instances of system complexity and system incoherence were identified within the students‘ NOS views (Chapter 4, page 130). Such instances were related to, for example, whether there is a single correct answer in science or if disagreements can exist amongst scientists, disbelief/doubt in science although it is empirically-based, and the role of confirmed facts vis-à-vis the use of imagination and estimation in science (issues arising from instances of system complexity and system incoherence are discussed in more detail later [page 225 and page 230]). These findings of instances of system complexity and system incoherence confirm previous reports that, at times, students‘ and teachers‘ NOS responses include some co-existing fragmented views that sometimes contradict each other (Abd-El-Khalick, 2006; Akerson & Hanuscin, 2007; Khishfe, 2008; Sutherland & Denick, 2002).

Significantly, the current findings relating to inconsistencies across students‘ levels of NOS understanding, and instances of system complexity and system incoherence within students‘ NOS views, draw attention to the inherent complexity of what constitutes an informed understanding of the nature of science. Indeed, it is recognised that the nature of science is ―multi-faceted [and] complex” (Abd-El-Khalick, 2006:391). The inherent complexity of NOS that is apparent from the findings of the present study, is depicted diagrammatically in Figure 5.2, and the associated explanations are indicated by means of numbered statements (listed below). The statements have been extracted from various international curriculum and reform documents (i.e., AAAS, 1989, 1993; NRC, 1996; NSTA, n.d.). In Figure 5.2, congruity between NOS aspects is indicated by means of solid lines, and apparent incongruity between particular aspects of NOS is indicated by means of broken lines.

- Scientific knowledge is simultaneously reliable and tentative, as new evidence may be found (1) or existing evidence might be reinterpreted (2) or new connections made (3).
- We can never be 100% sure about anything, although explanations are formulated and tested using observation, experimentation and accurate measurements (4)—and yet, observations are theory-laden (5) and influenced by researchers‘ personal knowledge, beliefs and expectations, as well as their social and cultural contexts (6).
- Also, scientists use their imaginations to consider different alternatives, and to make connections between data and explain how they fit together (7).
- It is therefore possible for scientists to reach different conclusions (8), although scientists seek evidence to resolve their disagreements (9).
- Accurate record-keeping, openness and replicability serve to maintain scientists‘ credibility, as well as vigorous verification processes (9), yet data may still be modified or abandoned in light of new evidence or interpretations (10).



KEY: — Agreement between NOS aspects
- - Apparent incongruity between NOS aspects

Figure 5.2: Depiction of the inherent complexity of an informed view of NOS

- Calculated predictions and theories are based on evidence collected (11), and this involves individual human insights, reasoning and skill (12), as well as scientists' creativity (13)—some explanations arise from speculations and some areas have yet to be resolved (2).

One simple, yet important idea can be inferred from Figure 5.2, namely, that an informed understanding of all five NOS aspects is somewhat internally coherent and thus complex. On the one hand, there are solid lines connecting each of the five aspects to each other. These solid lines represent coherent links between the various NOS aspects. However, there is one outlier, namely, the role of empirical evidence in science. Broken lines connect this NOS aspect to each of the other four aspects, where these broken lines represent incoherent links between the various NOS aspects. As such, the empirically-based aspect of NOS, which includes ideas concerning the accuracy and reliability of scientific knowledge and the role of empirical evidence in science, seems to be somewhat at odds with understandings that scientifically knowledge is tentative, theory-laden and subjective, socially- and culturally-embedded, and involves the use of imagination and creativity.

This complexity view of NOS holds important implications for science teachers. First, when teaching about NOS, it is recommended that science teachers do not underestimate the inherent complexities involved in generating an informed understanding of NOS in all its various aspects. Second, it is recommended that science teachers make explicit for students how the various aspects of NOS all work together. Allchin (2011:9) refers to this as a ―Whole Science approach". Previously it has been reported how individuals hold compartmentalised NOS views rather than integrating their understanding of target NOS aspects and making connections between them (e.g., Akerson et al., 2000). Consequently, there exists a need for science teachers to explain to students, in particular, the interplay between the empirically-based aspect of NOS on the one hand, and the tentative, theory-laden and subjective, socially- and culturally-embedded, and imaginative and creative aspects of NOS on the other. A possible useful avenue for future research is to explore how students' conceptions of the various aspects of NOS develop in relation to one another.

The internal coherence of students' NOS views is discussed next.

Coherence within the students' NOS views

A number of instances of system complexity and system incoherence were identified within the students' NOS views (Chapter 4, page 130), and therefore it can be considered that their NOS views were not completely coherent. The various instances of system complexity and system incoherence with the students' NOS views were related to six main themes, namely: (1) the aim/purpose of science; (2) the locations and methods of science; (3) disagreements in science; (4) relationships between different knowledge frameworks; (5) the role of empirical evidence in science in relation to disbelief/doubt in scientists; and (6) the relationship between confirmed facts and imagination/estimation in science (Chapter 4, page 130). These six themes help us to identify a number of important issues that science teachers are advised to discuss with their students in attempting to help them to develop NOS views that are more informed and more internally coherent.

In regard to the first theme (i.e., the aim/purpose of science), there arose issues concerning the aim/purpose of science, and the reasons for scientists doing their work. These issues highlighted the need for science teachers to engage students in discussions concerning science-technology-society issues, such as, the relationship between science and technology, the positive and negative impacts of science on the natural environment, and so forth. In regard to the second theme (i.e., the locations and methods of science), issues arose concerning where and how exactly scientists do their work. Consequently it might be helpful to provide students with detailed insights into the ways in which scientists work, including discussions of the great diversity of the fields of science as well as diversity amongst individual scientists. The third theme (i.e., disagreements in science) was related to what scientists know, and more specifically, disagreements amongst scientist and whether there exists only one correct answer in science. These issues suggest a need for students to be engaged in discussions concerning how disagreements amongst scientists arise, the ways in which scientists work towards resolving their disagreements, whether all disagreements can and need to be resolved, and how this impacts on the scientific knowledge that is made public. In regard to the fourth theme (i.e., relationships between different knowledge frameworks), instances of system complexity/incoherence within the students‘ NOS views raised issues concerning who can know things. Accordingly, it would be meaningful discuss with students how there are different ways of seeing and understanding the world (worldviews)—where a scientifically-inclined worldview and various religious worldviews are merely some of the alternative perspectives. Discussions might also include the roles of different knowledge frameworks in explaining natural phenomena, how the various worldviews can interact with one another, comparisons between specific views that form part of various worldviews, and how to manage opposing/conflicting explanations in the science classroom as well as in everyday life situations. The fifth theme concerned the role of empirical evidence in science in relation to disbelief/doubt in scientists. It is important that students learn ―what, or whom to trust” (Allchin, 2011:4). Therefore, it is recommended that science teachers discuss the following ideas with their students: the role of empirical evidence in science, the credibility and reliability of scientific knowledge, personal qualities such as intellectual honesty vis-à-vis errors in science, as well as the empirically-based aspect of NOS vis-à-vis the theory-laden, socially- and culturally-embedded, imaginative/creative, and tentative aspects of NOS. Finally, issues of system complexity/incoherence within the students‘ NOS views were related to the relationship between confirmed facts versus imagination and estimation in science (i.e., the sixth theme). These issues highlighted the need for the following to be discussed in science classrooms: the role of, and interaction between, empirical evidence and imagination/creativity and theory/speculation/estimation in the development of scientific knowledge, what is meant when referring to a scientific ―fact”, what it means to be creative and to use your imagination in science (as opposed to being imaginative and creative in other fields of study, such as fiction/non-fiction in language studies or art), the role of creativity in different types of scientific work (e.g., trying new methods for conducting tests and taking measurements, making connections between data, finding solutions to problems, developing new technology, etc.), and the role (e.g., value and use) of hypotheses and unconfirmed ideas in science.

In summary, this first part of Chapter Five has focussed on the results concerning the students‘ NOS views. Specifically, there has been a discussion of students‘ views about the work of scientists and the role/purpose of science. This was followed by a discussion of the levels of understanding of the students‘ NOS views, including a consideration of alternative meanings students assigned to various terms that they used in describing their views of NOS. Individuals‘ unique NOS profiles were then discussed, followed by a consideration of the richness and range of the students‘ NOS views, including their articulated mistrust and doubt in science, as well as the inherent complexity of concepts relating to various aspects of NOS. Finally, there was a discussion of the extent to which the students‘ NOS views are internally coherent. Implications for science teachers and NOS researchers have also been highlighted, including particular NOS-related ideas and terminology that need to be discussed and clarified with students, methodological recommendations for the collection and analysis of NOS data, and possible avenues for further research. Part Two of the discussion, which follows next, focuses on the results relating to the students‘ views of the natural world (i.e., Nature).

Part 2: Views of the natural world (i.e., Nature)

The second part of Chapter Five focuses on the results of the investigation into the students‘ views of the natural world. The students‘ definitions of Nature are discussed first, followed by a comparison of the students‘ various worldview profiles. Thereafter is a discussion of the inherent complexity of the question, ―What is Nature?”. The internal coherence of the students‘ views of the natural world is then considered. Finally, a number of questions needing further research are discussed. These questions arose from the students‘ responses relating to particular worldview descriptions.

Definitions of the natural world

In order to elicit the students‘ views of the natural world, it was necessary to determine what they understood by the term *Nature* (or the natural world/natural environment). Moreover, as previously explained (Chapter 4, page 106), as science is the study of the natural world, it was considered that the students‘ definitions of Nature might present some links with their NOS views.

In the present study, when defining what Nature is, a number of the students made a distinction between people and other species in the animal kingdom (e.g., Aaeesha, Gideon). Some students distinguished between that which results from natural and environmental processes, and man-made things (e.g., Brian, Dan, Dyllan, Samuel, Shafia, and Victoria). Moreover, the natural world was described as that which is untouched by people, that is, it has not been processed or transformed in any way (e.g., Aamir, Samuel, Shanon) (Chapter 4, page 138). Similar results have been reported in previous studies, where it was found that South Korean elementary school students (in Grades Five and Six) (Won et al., 2009) and junior-high students in Indiana, USA, (in Grades Seven to Nine) (Shepardson, 2005) typically viewed people as being separate from the natural world. Indeed, according to Soper (1995), Nature is distinct from humans. According to Kearney‘s (1984) worldview model, the natural environment is part of the universal worldview structure named the NonSelf or Other. Regarding the origin of natural phenomena, rather than being a product of human skill, Nature can be regarded as ―self-arising” (Bonnett, 2004:122)—in other words, that which has not been created by humans, and is derived from natural processes as opposed to social/cultural skills (Soper, 1995). Soper (1995) goes on to describe Nature as that which has not been artificially worked, shaped or produced by human activity. This view of Nature as self-arising was reflected not only in the present study, as indicated above, but also in a previous study concerning Fifth and Sixth grade students‘ perceptions of Nature and the environment (Bonnett & Williams, 1998). There it was found that students described Nature as something that is grown by itself and has not been planted, and is free from interference (Bonnett & Williams, 1998).

In addition to distinguishing between people and Nature, the students in the present study described elements that form part of Nature, including living things such as plants and animals, and phenomena such as natural disasters. The students also noted that Nature is found not only on Earth, but also beyond Earth (e.g., the rest of the solar system, including stars in the galaxy and moons, etc.). Bonnett and Williams (1998) reported similar findings, where Grade Five and Six students characterised Nature as living things, and the environment included everything on Earth and in the universe. Moreover, in the present study, students‘ descriptions of Nature as living things (both on Earth and beyond Earth) were coherent with their views of what scientists study and the aim/purpose of science—this point is discussed in Part 3 of the current Chapter (page 252).

The students‘ definitions of the natural world were discussed with them by way of introduction during the worldview interview, before the researcher proceeded to elicit details of their epistemological, ontological, emotional and status descriptions of Nature. Each student‘s view of Nature was summarised in the form of a worldview profile (Chapter 4, page 161), and these profiles are discussed next.

Comparison of the students’ various worldview profiles

Previous worldview studies using Cobern‘s (2000b) analytic framework, have reported great diversity amongst students‘ conceptualisations of Nature. ―[C]onsiderable conceptual variation” (Cobern, 2000b:42; Cobern et al., 1999) was found amongst the views of middle-class U.S. Grade Nine students. Won et al. (2009) also reported that the overall combinations of four worldview descriptions were diverse for South Korean Fifth and Sixth graders. Furthermore, they (Won et al., 2009) found that students‘ descriptions of the natural world were mostly not aligned with a single bipolar descriptor.For example, their responses included views that were both naturalistic and super-naturalistic, positive and negative, and resource-oriented and conservationist. Similar results were recorded in the present study, as discussed next. Accordingly, what follows is a discussion of the worldview results that relate to 1) the range of students‘ descriptions of Nature, 2) unique profiles depicting individuals‘ views of the natural world, and 3) diversity amongst the multiple cases.

Range of responses regarding the natural world

A range of responses regarding the natural world was elicited from the fourteen cases in this study. That is, epistemological views ranged from strongly Knowable to strongly Unknowable; ontological views ranged from strongly Naturalistic to strongly Super-naturalistic; emotional views ranged from strongly Positive to strongly Negative; and status descriptions ranged from strongly Resource-oriented to strongly Conservationist views. Table 5.1 presents a summary of these results, which have been presented individually in Table 4.11 (page 146), Table 4.12 (page 151), Table 4.13 (page 156), and Table 4.14 (page 160).

Notably, the students‘ views pertaining to a particular worldview description (e.g., epistemological description) often included statements that were aligned with both bipolar descriptors (e.g., both knowable and unknowable descriptions). This finding supports that of Won et al.‘s (2009) study which reported that South Korean Fifth and Sixth Grade students‘ descriptions of the natural world were mostly not aligned with a single bipolar descriptor. However, in their study, no finer distinction was made regarding the relative strengths of individuals' views pertaining to each of the four descriptions by, for example, locating individuals' views on a continuum as was done in the present study.

Table 5.1: Distribution of cases showing the diversity of their views of the natural world, presented as positions on a continuum (relative strengths of views) for each of the four worldview descriptions

Bipolar descriptor	++	+ -	**Partly**	- +	++	**Bipolar descriptor**
Knowable	1	7	1	3	2	Unknowable
Naturalistic	1	4	0	7	2	Super- naturalistic
Positive	4	6	1	2	1	Negative
Resource	4	4	0	3	3	Conservation

KEY: ++ indicates views that are *strongly aligned* with a bipolar descriptor; +- or -+ indicates views that are *not strongly aligned* with that particular bipolar descriptor

Notably, the students' views pertaining to a particular worldview description (e.g., epistemological description) often included statements that were aligned with both bipolar descriptors (e.g., both knowable and unknowable descriptions). This finding supports that of Won et al.'s (2009) study which reported that South Korean Fifth and Sixth Grade students' descriptions of the natural world were mostly not aligned with a single bipolar descriptor. However, in their study, no finer distinction was made regarding the relative strengths of individuals' views pertaining to each of the four descriptions by, for example, locating individuals' views on a continuum as was done in the present study.

As reported earlier, (Chapter 4, page 142) for each of the four worldview descriptions (i.e., epistemological, ontological, emotional, and status descriptions), the views of each student were not merely classified in terms of a combination of four bipolar descriptors (e.g., knowable or unknowable). Rather, the views of each student were located on a continuum according to the strength of alignment between their worldview descriptions and the various bipolar descriptor pairs (e.g., *strongly* knowable). This methodology was employed in response to the finding that the students' worldview descriptions included references to more than one bipolar descriptor (e.g., both Resource-oriented and Conservationist statements), and in light of the variations in the strength of the alignment of the students' views with particular descriptors.

Presenting the students' views on continua made it possible to unpack the richness and complexity of individuals' views, and to reflect the subtle differences, and the range of views, amongst the fourteen cases. In particular, it was possible to determine, for each worldview description (e.g., status description), which particular descriptor most accurately represented the individual‘s overall view (e.g., Conservationist) and consequently, to describe each student‘s view of the natural world in terms of a combination of four descriptors. Combinations of four continua for each case could then be further applied in constructing an overall profile of each student‘s view of Nature.

The worldview continua developed in this study therefore constitute a novel and useful way in which to analyse, describe and compare—in-depth—the rich, complex and diverse views of multiple individuals. Exploring the application of these continua in future studies involving students‘ views of Nature, presents an avenue for further research.

Unique profiles of students' views of the natural world

For each case, having located the student‘s views pertaining to each of the four worldview descriptions on a continuum, an individual overall profile could be compiled. A comparison of the profiles of the fourteen cases revealed that each one was unique. Indeed, only one profile was repeated (i.e., that of Samuel and Aaeesha) (Chapter 4, page 162). This finding, concerning the uniqueness of the students‘ worldview profiles, supports that of Won et al. (2009) who reported a lack of commonality amongst the overall combinations of four worldview descriptions for individual students. More significantly, this diversity holds implications for science teachers.

Students‘ worldviews comprise a set of beliefs that sum up what they know about the world, and provide a framework for the way in which students make sense of the world (Emereole, 1998; Gauch, 2009; Irzik & Nola, 2009; Kearney, 1984; Ogunniyi et al., 1995). In particular, students‘ views of the natural world—a component of worldview (Cobern, 1993)— influence how they make sense of what is presented to them in the science classroom (Allen & Crawley, 1998). Meaningful learning presupposes compatibility between students‘ worldviews and what is taught to them in science (Cobern, 1993). However, the results from this study suggest the possibility that a great diversity of views of Nature could exist in a single classroom. Although, we can expect that students might share some views regarding specific issues or aspects of the natural world, we need to recognise that it is unlikely for different individuals to hold identical views of the natural world. Furthermore, we need to consider the potential of drawing upon incompatible views as a means of stimulating discussion and reflection when learning science. These two issues are discussed again later (pages 242-3 and pages 258-9).

Diversity across the cases

The results reported in the previous chapter show that the purposive case selection strategy employed was successful in maximising diversity amongst the views of Nature represented by the fourteen students. Table 5.2 shows how the cases located at each of the various positions on the four worldview continua represented diverse religious groups, where religion was used as a cultural marker of diversity in selecting respondents. The possible impact of this case selection strategy has already been discussed (Chapter 5, page 214).

Table 5.2: Diversity of worldview descriptor locations represented by students from the various religious groups

Bipolar descriptor	++	+ -	Partly	- +	++	Bipolar descriptor
Knowable	1C	3M,3J,1C	1C	2M,IJ	1M,1J	Unknowable
Naturalistic	1M	3J,1C		3M,2J,2C	2M	Super-naturalistic
Positive	2M,1J,1C	2M,4J	1M	2C	1M	Negative
Resource	3M,1C	2M,2J		2J,1C	1M,1J,1C	Conservation

KEY: ++ indicates views that are *strongly aligned* with a bipolar descriptor; +- or -+ indicates views that are *not strongly aligned* with that particular bipolar descriptor; M: Muslim cases; J: Jewish cases; C: Christian cases

The diversity of views of the natural world described by the students in this study supports the assertion that a number of different possible worldviews exist (e.g., scientific, philosophical, religious and cultural worldviews). What is more, even amongst religious worldviews, for example, a number of variations can be found (e.g., there is no single Islamic worldview) (Irzik & Nola, 2009).

Further to the range and diversity of worldview responses recorded in this study, the results hold implications regarding the inherent complexity of the concept of Nature, as discussed next.

Inherent complexity of concepts relating to views of the natural world

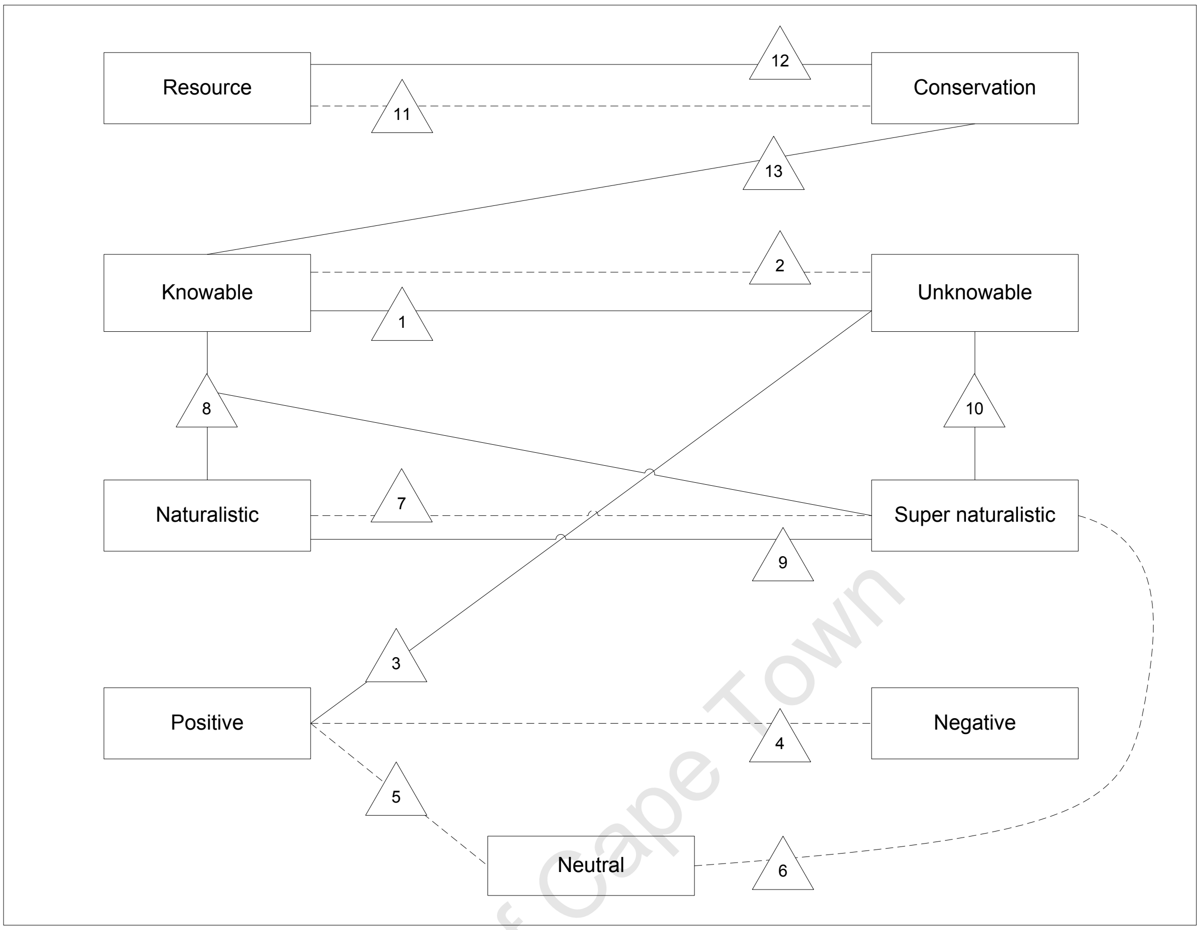
A review of the research literature about the natural world reveals how the concept of Nature is complex (Chapter 2, page 32). For example, Nature is simultaneously chaotic and ordered, machine-like and organismic, savage and noble, wholesome and polluted (Soper, 1995). In the present study, the students' descriptions of the natural world included references relating to various fundamental concepts about Nature (Chapter 2, page 32; Chapter 4, page 142). Furthermore, it was found that the students described a range of views about Nature (Chapter 4, page 142 and page 161), and that their worldview descriptions included instances of system complexity and system incoherence (Chapter 4, page 162). Each of these points will now be discussed, in turn, followed by a discussion of the implications of these results for science education researchers and science teachers.

In regard to the first point concerning the students' range of views about Nature, in the present study it was found that the students' worldview descriptions included references to the various concepts identified by Soper (1995) and Bonnett (2004, 2007). In particular, aspects of a *metaphysical concept* of Nature, concerning the distinction between humans and Nature (Bonnett, 2004; Soper, 1995) were reflected in the students' descriptions of people, man-made things and transformative processes as being separate from the natural world (Chapter 4, page 138). A metaphysical concept of Nature concerning the sustainable use of Nature was reflected in the students' conservationist worldview descriptions (e.g., relating to how and why we need to protect Nature) (Chapter 4, page 157). A *realist concept* of Nature, concerning physical processes and causality, and the interrelatedness of everything in Nature (Bonnett, 2004; Soper, 1995), was evident in the students' knowable worldview descriptions (e.g., that there is order in Nature that we can observe and study in science), as well as in their naturalistic descriptions of physical causes in Nature (Chapter 4, page 148). A realist concept of the natural world also concerns the notion that people are always subject to the laws of Nature (Bonnett, 2004, 2007; Soper, 1995). In the present study, this realist idea of being subject to Nature was reflected in the students' descriptions of the natural world as unknowable (e.g., Nature is unpredictable and cannot be controlled) (Chapter 4, page 143) as well as in their super-naturalistic worldview descriptions (e.g., personified images of Nature and descriptions of transcendental purposes of natural events) (Chapter 4, page 148). This aspect of a realist view of Nature was also reflected in the students' resource-oriented worldview descriptions (regarding Nature's resilience over man's negative impact, and Nature's ability to repair itself) (Chapter 4, page 157). Bonnett's (2004, 2007) notion that people will never fully know everything about Nature was reflected in the students' references to aspects of Nature that remain mysterious and which have not yet been discovered (Chapter 4, page 142). A realist concept of Nature further concerns the ways in which people transform Nature (e.g., using natural resources, and resultant waste, pollution and destruction) (Soper, 1995), and this, in turn, is related to a lay/surface concept of Nature (i.e., regarding that which people have destroyed and polluted and need to conserve) (Soper, 1995). These conservationist ideas about Nature were reflected in the students' descriptions of the natural world as polluted, endangered, over-used, ruined, and so forth (Chapter 4, pages 157-8). A *lay/surface concept* of the natural world relates to emotional responses to Nature, for example, the notion that the natural world can be ordinarily and directly observed and/or experienced (Soper, 1995). Emotional responses to Nature also relate to an aesthetic appreciation of Nature and people's feelings towards Nature

(Soper, 1995). In the present study, such views were reflected in the students‘ emotional descriptions of Nature as everyday and ordinary (Neutral) (Chapter 4, page 153), likeable, colourful and beautiful (Positive) (Chapter 4, page 152), as well as descriptions of descriptions of Nature being ―too girlie” (Aamir), boring, and even dangerous and frightening (Negative) (Chapter 4, page 153). The students‘ views of the natural world were therefore complex in that they included references to multiple theoretical concepts regarding Nature.

Previous worldview research involving U.S. Ninth graders (Cobern, 2000b; Cobern et al., 1999) reported how students conceptualised Nature as a combination of different perspectives (e.g., aesthetic, religious, conservationist). The results from the present study similarly show that the students described a range of views regarding the natural world. For each worldview description, diverse examples from various cases supported views relating to more than one bipolar descriptor (e.g., both Knowable and Unknowable epistemological views) (Chapter 4, page 143). Moreover, *individual* students typically described examples relating to more than one bipolar descriptor (Chapter 4, pages 143, 149, 153 and 158). In addition, the students‘ views of the natural world contained a number of instances of system complexity and system incoherence (Chapter 4, page 162). The range and richness, and internal complexity/incoherence of these results, reflect how the concept of Nature is inherently complex. The complexity of Nature is represented diagrammatically in Figure 5.3, where agreement between various ideas about the natural world is represented by means of solid lines, and apparent incongruities between particular aspects of the concept of Nature are represented in the form of broken lines. The statements which follow illustrate the various points of agreement and/or incongruity between worldview descriptors. These illustrative statements have been extracted from the data in the present study concerning students‘ views relating to the various bipolar descriptors, as well as from instances of system complexity and system incoherence that were identified within the students‘ views of Nature. The statements have been loosely organised according to each of the four worldview descriptions (i.e., epistemological, emotional, ontological, and status descriptions).

The students‘ worldview descriptions included views that the natural world comprises a diversity of species, sizes and locations (unknowable) but it is understandable and we can learn things about Nature (e.g., we can differentiate between different species) (Knowable) (1). We already know so much about the natural world, but we should study and learn more (Knowable), because some things are complicated and confusing, and there remains more to be discovered still (Unknowable) (1).



KEY: — Agreement between worldview descriptions; - - Apparent incongruity between worldview descriptions
Figure 5.3: Diagrammatic representation of the inherent complexity of the concept of Nature

There are observable patterns and cycles in Nature, and things happen for a reason (Knowable), although plants do not grow in orderly rows, and events such as natural disasters cause chaos (Unknowable) (2). We can forecast cause-effect relationships and seasonal changes that occur in Nature (Knowable), as there is some order in Nature and future events are predictable (Knowable). However, Nature is also changeable and somewhat unpredictable (Unknowable), and there are some strange things that are unexplained (Unknowable) (2).

We should study the natural world and learn more about it (Knowable), although it is good for some mysteries to remain unresolved (Unknowable) (2) in order that people continue to enjoy simply being in Nature (Positive) (3). There are various places and activities to be enjoyed in Nature (Positive). The natural world is peaceful and good (positive), although some natural phenomena are dangerous, frightening and harmful to us (Negative) (4). Nonetheless, Nature is fascinating and beautiful (Positive), and we therefore need to appreciate it more (Positive)—

even though some of it is ordinary and we see some things every day (Neutral) (5).

The natural world is ‗just there‘ (Neutral, Naturalistic), yet it can provide a spiritual experience for some people (Super-naturalistic) (6). God created Nature, therefore it is holy and spiritual (Super-naturalistic), although people do not pray to things in Nature (Naturalistic) (7). Natural events have physical causes and result from material processes (Naturalistic) (8), although some natural events are explained in terms of transcendental purpose (Super-naturalistic) (9)—perhaps when naturalistic causes are unknown or uncertain (10). There are conflicting explanations about Nature, for example, concerning the origin of the Earth (e.g., perhaps God created the Earth, and then there was a Big Bang, followed by evolutionary processes (Super-naturalistic and Naturalistic) (9).

Nature is useful and we need to use it (Resource-oriented). People do not use everything in the natural world (Resource-oriented), although they are chopping down too many trees, over-fishing, and using too many natural resources such as fuel and water (Conservationist) (11). Therefore, in addition to using Nature, we also need to protect it from being destroyed (Conservationist). This is because people are ruining Nature, and the natural world is polluted and endangered (Conservationist) (12). That said, however, Nature is resilient and there will always be more (Resource-oriented) (11). Nature repairs itself (Resource-oriented), although some parts that are ruined (e.g., damage to the ozone layer, global warming, or extinct species) cannot be restored (Conservationist) (11). We should learn more about Nature in order to protect it (13).

Figure 5.3 and the associated explanatory statements illustrate how the concept of Nature includes views belonging to multiple bipolar descriptors (in the form of both coherent and incoherent links), and is therefore inherently complex.

In light of the complexity view of Nature presented here, it can be argued that the concept of Nature should not be reduced to a limited combination of bipolar descriptors such as, for example, depicting a scientifically-inclined view of Nature as being Knowable, Naturalistic, Positive, and either Resource-oriented or Conservationist (Chapter 2, page 35). Indeed, Cobern (2000b:47) asserts that the notion of a single scientific worldview ―is at best...problematic”. Therefore, rather than presenting such a narrow view of the natural world in science education, it is necessary to emphasise the inherent complexity of the concept of Nature. This complexity view of Nature holds implications for science education research and science teaching, as detailed next.

Methodological implications for science education researchers

The complexity of understanding a concept such as Nature should not be underestimated. Consequently, when investigating students' views of the natural world, it is recommended that researchers aim to elicit detailed and nuanced descriptions from respondents. In the present study, Cobern's (1991, 2000b) structured world view interview was found to be an effective tool for eliciting detailed descriptions of the natural world from each student. Although ‗Nature' could be regarded as a broad and somewhat obscure and unusual subject for discussion, the activity-based nature of the worldview interview and the use of various elicitation devices helped to concretise the discussion for the students. Employing a think-aloud approach and encouraging the students to provide examples to illustrate their views, further helped to clarify their responses and to establish links between statements during the analysis of the data. Although the use of a highly structured interview schedule was constraining to some extent, it facilitated a greater degree of uniformity in studying multiple cases. The structure also helped to maintain focus during the interview, whilst still allowing space for the interviewer to probe particular responses further where necessary. The structure of the interview schedule also made allowance for school timetable restraints and Grade Six attention spans (Chapter 3, page 56 and page 85).

In addition to data collection procedures, a complexity view of the natural world holds implications for the analysis of such data. Specifically, there is a need to reflect the subtle variations in respondents' descriptions of the natural world. To this end, in the present study it was helpful to locate each student's views on a continuum that reflected the relative strengths of their views regarding each worldview description (e.g., emotional descriptions: strongly Positive, Positive, Neutral, Negative, strongly Negative). In so doing, the structure of Cobern's (1991, 2000b) methodology involving four worldview descriptions (i.e., epistemological, ontological, emotional, and status descriptions) was extended beyond merely categorizing individuals' views of Nature in terms of a combination of bipolar descriptors (e.g., Knowable, Naturalistic, Positive, and Resource-oriented). The application of worldview continua is an analytic approach that can be explored and refined in future worldview research.

Implications for science teachers

The concept of Nature that is currently taught in schools is implicit and piecemeal, which is problematic in regard to the views of the natural world that students develop (Bonnett, 2004). Furthermore, it would seem that students are rarely engaged in general discussions about Nature. In the present study, students' responses revealed that being provided with opportunities to reflect upon and discuss their ideas about the natural world was a novel experience for them. Significantly, the students' responses indicated that they not only enjoyed the discussions, but that they also found them to be valuable and affirming learning experiences. More importantly, students felt that their conceptualizations of the natural world had improved, simply as a result of being granted opportunities to reflect upon and describe their views (Appendix 5.1, page 429).

Therefore, in order to help students to develop an appropriate understanding of the natural world in all its complexity, it is recommended that science teachers provide opportunities for students to discuss their ideas about Nature. In particular, it is recommended that students be presented with a view of the complexities inherent in the concept of Nature (as previously recommended by Lynch [1998])—this would be a scientifically-compatible view in a more true sense, and one which would enable students to develop more informed views regarding our knowledge of the natural world and how it is developed, that is, the nature of science.

What follows next is a discussion concerning the internal coherence of the students' views of the natural world.

Coherence within the students' views of the natural world

According to Kearney (1984:41), a person's worldview "consists of basic assumptions and images that provide a more or less coherent...way of thinking about the world". However, Kearney (1984) points out that worldviews have never been entirely consistent. Inconsistencies can occur, for example, as a result of contact between people with different worldviews, such as interactions between students in culturally diverse classrooms (such as those found in South African schools). Inconsistencies can also occur as a result of conflicts between the views presented to students at school compared to those they encounter at home. Such inconsistencies might give rise to what science education researchers refer to as border-crossing (e.g., Aikenhead, 1996; Phelan et al., 1991). What follows next is a discussion of the results relating to border-crossing and conflicts between alternative explanatory frameworks. Thereafter a number of issues, arising from instances of system complexity and system incoherence within the students' views of the natural world, are considered.

Border-crossing and Collateral learning

In the present study, the students' descriptions of the natural world contained examples of differences—and, in some cases, explicit conflicts—between naturalistic and super-naturalistic explanations of Nature, and/or between science and religion (Chapter 4, page 194). Victoria, Gideon and Shafia managed the differences between scientific and religious explanations by establishing connections between the two explanatory frameworks (Chapter 4, pages 195-6). Shanon managed the perceived differences by keeping religion and science separate from one another in her conceptual framework (Chapter 4, page 194). However, for Dyllan, border-crossings were hazardous, and for Brian, border-crossings were impossible. For Dyllan and Brian, the conflicting explanatory frameworks of science and religion remained incompatible, and one worldview dominated over the other (Chapter 4, pages 198-9). Similar findings were reported in Cobern's (2000b) study of U.S. Grade Nine students' conceptualisations of Nature, where some students articulated a contradiction between their religion and their scientific understanding of Nature. These worldview conflicts posed confusing and difficult dilemmas for them. However, other students held both scientific and religious views simultaneously without discomfort. In some cases, science and religion were assigned distinct roles in respect to Nature, and thus there was no conflict (Cobern, 2000b).

Furthermore, analysis of coherence for the six students who described border-crossing experiences and science/religion conflicts, revealed that although their worldview descriptions contained instances of system complexity and system incoherence, these worldview descriptions were coherent with their views of NOS. Indeed, the results concerning students' descriptions of worldview differences and conflicts become more meaningful when one considers the overall levels of NOS understanding of the six students mentioned above (i.e, Victoria, Gideon, Shafia, Shanon, Dyllan and Brian). Victoria, Gideon and Shafia held views that were largely informed. Shanon's NOS views were somewhat informed. Dyllan and Brian held NOS views that were developing (Chapter 4, page 199). Therefore it would seem that students for whom border-crossings are managed—albeit by means of compartmentalising their views or holding compromise views—held NOS views that were overall either somewhat or largely informed. In contrast, the students for whom border-crossings were unsuccessful (e.g., hazardous, impossible)—due to incompatible and irreconcilable differences between different worldviews—held NOS views that were more naive. The implications of these findings for science teaching are presented next.

Implications for science teaching

The first implication concerns the diversity of possible worldviews that can exist among people, that is, students need to become aware that there is more than one way of viewing the world, such as scientific worldviews, cultural and religious worldviews. Moreover, amongst religious worldviews, for example, there is no single Islamic worldview, and there can be a number of scientific worldviews as well (Irzik & Nola, 2009). Consequently, it is recommended that science educators help students to see that their own religious worldview is not the only worldview (Glennan, 2009:811), and that students can learn about the scientific view without necessarily taking the view to be their own (Aikenhead, 1996; Hansson & Redfors, 2007a; Ogawa, 1995)—this is a cross-cultural view of learning. Indeed, the primary goal of science education is not to change belief, but to develop students‘ knowledge and understanding of the content, processes, and nature of science and the development of scientific knowledge (Allchin, 2011; Alexakos, 2010; El-Hani & Sepulveda, 2010). It is thus possible for religious individuals to develop a scientifically-compatible worldview (Cobern, 2000b).

The second implication concerns the nature of science. ―Questions about the relationship between science and religion captures questions about the nature of science, such as the presuppositions of science, the borders of scientific knowledge, how one views knowledge in science, etc.” (Hansson & Redfors, 2007a:465). Therefore, it is suggested (Hansson & Redfors, 2007a, 2007b; Stanley & Brickhouse, 1994) that when teaching about the nature of science, science teachers initiate discussions about presuppositions in science. During such discussions, it is recommended that teachers re-emphasise that science is a way (not *the only way*) of thinking or of making sense of the processes of the natural world. Students should further be encouraged to interrogate scientists‘ beliefs and procedures and the ways in which conclusions are reached and decisions and choices made during the process of the development of scientific knowledge (Alexakos, 2010). Also, there is a need to hold group discussions with students in which they become aware of their own views and start to problematise them (Hansson & Redfors, 2007b). ―The best strategy is to focus on students‘ understandings of science and about science, and offer them grounds to be critical, reflexive, and open-minded towards human knowledge in all its variety” (El-Hani & Sepulveda, 2010:122).

According to El-Hani and Sepulveda (2010), it is not necessary that students have a logically coherent worldview, as they can live with large amounts of cognitive dissonance. More specifically, differences between students‘ personal worldviews and the worldview they associate with science need not necessarily pose a problem for all students—what is important is how students manage to deal with the conflicts they experience (Hansson & Lindahl, 2010).

The third implication concerns border-crossings in science. In light of the variety of possible worldviews that exist, it is suggested that rather than discussing broadly the differences between particular worldviews, one should ask more *specific* questions about the relationship between various scientific and religious presuppositions, beliefs, theories and practices (for example, a reliance on faith as opposed to commitments to evidence; belief in God versus a commitment to naturalism; commitment to truth and sacred texts as opposed to scientific canons of evidence, and differences between theories such as creationism as opposed to Big Bang and Evolution theories) (Glennan, 2009). In so doing, as recommended by Cobern (1989, 2000b), science teachers might help students to build bridges that connect science with other important aspects of their lives. Indeed, if students hold more informed NOS views they might be more likely to understand better the relationship between science and religion, which could help alleviate the tension between the two (D.D. Lee, 2003).

What follows next is a presentation of particular issues that need to be addressed in science classrooms. These issues arose from the various instances of system complexity and system incoherence within the students' views of the natural world.

Issues arising from instances of system complexity and system incoherence within the students' views of the natural world

Students' worldviews have been found to contain inconsistencies (e.g., Liu & Lederman, 2007). Indeed, in the present study, there were a number of instances of system complexity and system incoherence (and explicit conflict) within the students' views of the natural world. These instances of internal incongruency reveal a number of Nature-related issues that it is recommended for teachers to address in the science classroom. Discussing these issues will provide opportunities for students to reflect on these matters and perhaps, in turn, to assist them to develop more internally consistent ideas about the natural world. The various issues are summarised in Table 5.3, and arranged according to each of the four worldview descriptions, namely, issues relating to epistemological, ontological, emotional and status descriptions of the natural world.

Table 5.3: Issues arising from instances of system complexity and system incoherence within the students' views of the natural world

Epistemological issues	• How much do we understand about the natural world? What has been discovered/proven and how much remains undiscovered and unknown/unexplained? • How much of Nature can we know? How much more will we be able to know and explain in the future? To what extent is Nature orderly and explainable? • To what extent can natural events/phenomena be predicted and prevented? There is a need to distinguish between the changeability and predictability of the natural world, and people's abilities to make predictions; and also to distinguish between the ability to forecast and prevent what will happen, and the ability to minimise the impacts of such events/phenomena in Nature.

Table 5.3 (cont...)

Epistemological issues	• How do we find out things about the natural world? There is a need to talk about knowing through everyday observations and experiences, as opposed to carrying out formal research studies; also to discuss how to make sense of different domains of knowledge about the natural world (e.g., scientific accounts vs. religious beliefs). • Why/do we need to study Nature further? What is the relationship between increased knowledge of Nature and enjoyment/appreciation of Nature and using/protecting the natural environment?
Ontological issues	• Discussions might include how we can experience and observe the natural world as an everyday phenomenon, as well as experiencing Nature as a holy and spiritual place. • How was Earth formed? Making sense of naturalistic explanations (e.g., science: Big Bang, evolution) and super-naturalistic explanations (e.g., religious views: creationism) regarding the origin of the Earth. • Why do things happen in Nature? Making sense of naturalistic explanations of physical causes/purposes and processes as opposed to views of transcendental involvement and Divine purposes. • Who can know about Nature: people or God? • Do we believe scientists or do we rather believe in God? How do we negotiate contrasting explanations about the natural world?
Emotional issues	• Is Nature just an ‗everyday' part of life and how much do/should we appreciate the natural world? Is Nature ―just there" or do we need to go to Nature to experience it?
Status issues	• To what extent does Nature restore itself? To what extent is Nature being over-used and ruined? • There is a need to discuss the sustainable use of natural resources (i.e., finding a balance between viewing Nature as a resource and recognising the need to conserve and protect the natural environment).

Questions arising from the students' responses relating to the four worldview descriptions, which constitute possible avenues for further research

Further to the preceding discussion of the results concerning the students' views of the natural world, a number of questions arose from the students' responses to particular worldview descriptions (i.e., epistemological, ontological and emotional worldview descriptions). From these questions, a number of areas for further research have been identified and are mentioned below.

Epistemological descriptions

Results pertaining to the students' epistemological worldview descriptions raise questions concerning the possible impact of science teaching on students' views of Nature, the possible relationship between students' academic ability levels and their epistemological worldview descriptions, and the relationship between epistemological worldview descriptions and students' age/grade levels.

Possible impact of science teaching on students' epistemological views of Nature

A large number of the students' epistemological worldview descriptions were located on the Knowable side of the Knowable-Unknowable continuum. This might be considered a surprising result, in lieu of the fact that the students are only in Grade Six (11-12 years old) and therefore cannot yet know all there is to know about Nature. Therefore perhaps this result reflects the way in which the natural world is presented to students in the science classroom: it is reasonable to expect that students are typically taught what is known about Nature, including natural patterns and laws, by a science teacher who possesses a reasonable amount of knowledge about the natural world. Uncertainties about the natural world are not likely to receive much emphasis during science lessons. It is beyond the scope of the present study to examine this assertion, but the relationship between students' epistemological worldview descriptions and the image of Nature that is presented to them in the science classroom, constitutes a possible avenue for further research.

Possible relationship between academic ability levels and epistemological descriptions

It might be considered that students' epistemological worldview descriptions will be a reflection of their academic ability levels. For example, students of low academic ability might describe Unknowable views of the natural world (e.g., that Nature is confusing, complex and unknown) stemming from their own limited knowledge and understanding about Nature. In contrast, students of high academic ability level might view Nature as understandable, based on the knowledge they have acquired about natural phenomena (i.e., a Knowable view of Nature). However, results of a previous study involving U.S. Grade Nines found an apparent lack of correlation between students' academic performance in science and their views about Nature (Cobern, 2000b; Cobern et al., 1999). Unfortunately, due to limitations of the data collected in the present study (page 213), this idea could not be examined further. Consequently, the relationship between students' academic ability levels and their epistemological descriptions of the natural world could not be explored in the present study, although this constitutes a possible avenue for further research.

Relationship between epistemological worldview descriptions and age/grade level

In describing things in Nature that are unknowable, one student remarked, ―I‘m thirteen[15] years old! So I don‘t know that much…I don‘t know everything…” (Gideon). Gideon‘s comment highlights an important question for worldview researchers, concerning the relationship between age (or grade level) and epistemological worldview descriptions. For example, are younger students more likely to describe Nature as being unknowable than older students, simply because they have not yet acquired as much knowledge about the natural world as their older peers? It was beyond the scope of the present study to answer this question. Cobern (2000b) has also raised a question concerning whether and/or how students‘ conceptualizations of Nature change with increasing age and maturity. This question therefore constitutes the possible focus of a future study.

Ontological descriptions

Classification of the students‘ overall ontological descriptions raised issues pertaining to their self-identified religiosity. All the students self-identified themselves as having a strong religiosity and, indeed, in almost all cases, their ontological descriptions included references to God creating Nature. It is therefore not surprising that a large proportion of the fourteen cases were located on the Super-naturalistic end of the Naturalistic—Super-naturalistic continuum. This said, however, it is perhaps surprising that only two students described ontological views that were strongly Super-naturalistic (S++). Moreover, four students‘ views were classified as Naturalistic (N+S-) and one student‘s views were strongly Naturalistic (N++). These results concerning the students‘ ontological worldview descriptions might be related to differences between declarative knowledge and personal knowledge.

In the science education research literature, a distinction is sometimes made between personal or proximal knowledge and declarative or distal knowledge, where the terms proximal and distal reflect distances from personal, lived experience (e.g., Hogan, 2000). Essentially, proximal knowledge comprises an individual‘s personal understanding and beliefs, whereas distal knowledge comprises knowledge and awareness which is not necessarily internalised by the student. Furthermore, personal and declarative knowledge are not necessarily the same for the individual, although the two types of knowledge interact with one another. Hogan (2000) raises two important questions in his discussion of proximal and distal knowledge: To what extent does students‘ declarative knowledge differ from their personal knowledge? Are we

[15] Previously, it has been stated that the students participating in this study were 11-12 years old (Grade Six). Gideon‘s birthday happened to fall during the period of data collection at his school, and thus, he was no longer twelve at the time of his interview—he had just turned thirteen.

measuring knowledge or belief structures? Although Hogan‘s (2000) questions relate specifically to studies of students‘ NOS views, they might equally be applied to a study of students‘ views of the natural world.

In the present study, the fourteen students all self-identified themselves as belonging to a particular religion, which presupposes a strong religiosity. However, the worldview data show that the students did not all hold strongly Super-naturalistic views of the natural world. Therefore, perhaps their self-identified religiosity was declarative knowledge as opposed to reflecting their personal beliefs. This notion requires additional exploration, by probing students further in order to distinguish between their declarative knowledge and their personal beliefs, and to explore the extent to which the students‘ declarative and personal knowledge differs from one another. Such an analysis was beyond the scope of the present study, but constitutes a possible focus of a future study.

Emotional descriptions

A brief comparison of the students‘ overall emotional descriptions by gender (Chapter 4, page 156), raised a question regarding the difference between boys‘ and girls‘ views of Nature. Results concerning the students‘ emotional worldview descriptions show that four cases held neutral or negative views of the natural world and, significantly, these cases were all boys. Furthermore, one of these boys (Aamir) stated that he did not like Nature ―because it is too girlie”. The term ―girlie” was used as a derogatory term to describe something as effeminate. Aamir went on to describe different kinds of activities that he associated girls and boys doing (e.g., during a visit to the forest). A similar finding was reported by Bonnet and Williams (1998), where Grade Five and Six students‘ descriptions of Nature as boring, were usually made by the boys (e.g., in response to a picture of a forest or a meadow). In contrast to Bonnet and Williams‘ (1998) results, however, Cobern (2000b) found no meaningful gender differences in his Grade Nines students‘ conceptualisations of Nature. Questions therefore remain concerning possible gender differences in regard to emotional descriptions of the natural world, and how these might be related to students‘ experiences of gender-specific (albeit stereotypical) experiences of Nature.

In Part 2 of the present chapter, the discussion has focussed on the results relating to the students‘ views of the natural world. First, the students‘ definitions of Nature were discussed. This was followed by a discussion relating to the range and diversity of views described by the students, including their unique worldview profiles. The inherent complexity of the concept of Nature was then argued. This was followed by a discussion of coherence within the students‘

views of the natural world, in terms of issues relating to border-crossing, in/compatibility between alternative explanatory frameworks, as well as specific issues arising from instances of system complexity/incoherence within the students‘ views of the natural world. Some additional comments were then mentioned about the results pertaining to particular worldview descriptions. Part 3, which follows next, involves a discussion of the results concerning coherence of the students‘ views of NOS and their views of Nature.

Part 3: Coherence

The relationship between worldviews and NOS understanding has been previously identified as an area of much-needed research (N.G. Lederman, 2007) and constituted the main research question of the current study. The results show that the students described diverse views of the natural world, but that there was no obvious relationship between their worldview profiles (i.e., the combination of worldview descriptors according to which each student‘s views of the natural world were classified) and their NOS profiles (i.e., overall levels of understanding about each NOS aspect). It is asserted that this lack of a significant relationship reflects not only the inherent complexity of what is Nature and what the natural world is like, and the inherent complexity of what constitutes an informed understanding of the nature of science, and but that it also reflects the complexity of the coherence between these two domains. This point is discussed further in a later section (page 189).

In light of the complex relationship between the students‘ views of Nature and of NOS, and the lack of obvious relation between individuals‘ worldview profiles and their NOS profiles, a more in-depth analysis of coherence was carried out. This in-depth analysis began with an examination of coherence between students‘ definitions of Nature and their views of the work of scientists (Chapter 4, page 180). Coherence analyses further involved the examination of coherent and incoherent links between statements about Nature and statements about NOS (discussed in terms of themes), and subsequently analysis of links between themes and levels of NOS understanding in general (Chapter 4, page 181 and page 184), as well as analysis of links with specific levels of understanding about each aspect of NOS (discussed in terms of emerging issues that teachers need to address in the science classroom) (Chapter 4, page 189). The results of these various components of the coherence analysis will now each be discussed in turn. In addition, there is a discussion concerning the overall coherence of the students‘ views, as well as a reflection on the usefulness of applying explanatory coherence principles during the data analyses.

Coherence between students' definitions of Nature and their views of the work of scientists

Drawing upon Kearney‘s logico-structural worldview model (1984), and in line with Cobern‘s (1989, 1993, 1999, 2000b) worldview research methodology, the focus of the worldview component of the present study was on a subdivision of the universal worldview category NonSelf, namely, Nature, or the natural world (Chapter 2, page 30). This is because Nature is the domain in which the natural sciences operate (Cobern, 1991, 1993). In order to answer the third research question of the present study, concerning coherence between students‘ views of the natural world and their views of NOS, the data were analysed for evidence of any links, albeit coherent or incoherent, between the students‘ descriptions of Nature and their NOS statements.

During the first task of the worldview interview, a number of questions were posed to students in order to elicit initial links between their views of Nature and of NOS (i.e., to what extent people can know things about Nature, and how people come to know such things, etc.) (Chapter 3, page 89). However, in order to ensure that any such links were self-arising from the students and not in response to prompts from the researcher, no explicit references to science or scientists were made during the worldview interviews. Similarly, when taking about their views of NOS, particular references to the natural world arose from the students‘ themselves. Even so, evidence was found of students making their own connections between the natural world and science.

During the analysis of coherence, coherent links were established between students‘ views of what Nature is and how we can know things about the natural world, and their views of what scientists study and the aim/purpose of science (Chapter 4, page 180). For example, students identified scientists as people who study Nature (Chapter 4, page 181), and they also identified particular aspects of Nature that are studied in science (e.g., plant and animal species, weather-phenomena, outer space, etc.). Moreover, students described that one of the aims of science is to gain increased knowledge of the natural world (Chapter 4, page 181). The students therefore recognised that Nature is the domain in which science operates.

Further to the above, in-depth examination of coherence between the students‘ views of the natural world and their views of NOS provided some important insights into the complex relationship between these two domains, as discussed next.

Links between themes and levels of NOS understanding

Analysis of all the coherent and incoherent links between the students‘ views of the natural world and their NOS views revealed little regarding the relationship between particular descriptions of the natural world (e.g., Unknowable) and particular levels of understanding pertaining to each of the various NOS aspects (e.g., informed and naive views of the theory-laden aspect of NOS) (Chapter 4, page 181). Consequently, the total 197 links were analysed according to the five clusters of themes previously identified amongst them (i.e., Knowing and finding out, Sure knowledge, Unsure knowledge, Choosing an explanatory framework, and Interactions/transactions) in terms of coherence with particular levels of understanding for each NOS aspect (Table 4.18, page 187). The procedure for conducting this analysis is explained next, and a synopsis of the results hereof is presented in Table 5.4. Numbered references within Table 5.4 relate to Figure 5.4 (page 256).

Table 5.4: Summary of links between clusters of themes and levels of NOS understanding

CLUSTER OF THEMES			**NOS ASPECT**		
	Tentative	Empirical evidence	Theory-laden	Social / Cultural	Imagination & creativity
Knowing and finding out	Informed, Developing (12,13)			Developing, Naive (19)	Naïve (20)
Sure knowledge	Developing, Naïve (1)	Informed (4, 4)			Naive (Informed) (11)
Unsure knowledge	Informed, Developing, (Naive) (1)				
Choosing an explanatory framework				Informed, Developing (Naive) (15)	Informed (Naive) (16)
Interactions/ transactions			Developing, Naive (17)	Informed* (18)	

KEY: Parentheses ( ) indicate incoherent links; * indicates links related to inventing and developing things; Green shaded blocks indicate where clusters of themes were coherent with informed and developing NOS understandings; Red shaded blocks indicate where clusters of themes were coherent with naive and developing NOS understandings; Blocks were left unfilled were no clear synopsis could be compiled of the links between a particular cluster of themes and a particular NOS aspect.

For each cluster of themes, the links relating to each aspect of NOS were examined in turn, in order to obtain a global view of the links between the cluster and the NOS aspect. For example, between the cluster of themes *Knowing and finding out* and the tentative aspect of NOS, there were eight coherent links with informed views, five coherent links with developing views, but only one coherent link with naive views (Table 4.18, page 187). Overall, therefore it was considered that the majority of links relating to *Knowing and finding out* were coherent with informed and developing levels of understaning about the tentative aspect of NOS (Table 5.4).

For a number of clusters of themes, however, a synopsis of the various coherent and incoherent links with a particular NOS asptect could not be easily compiled. First, in a number of clusters there were similar numbers of links related to multiple levels of NOS understanding. For example, links between the first cluster of themes (i.e., *Knowing and finding out*) and the theory-laden aspect of NOS were *coherent* with informed (one link), developing (two links) and naive (3 links) levels of understanding, whilst also being *incoherent* with informed (two links), developing (two links) and naive (two links) levels of understanding (Table 4.18, page 187). Second, in other clusters, some of the links were seemingly contradictory. For example, concerning the cluster of themes *Knowing and finding out* and the empirically-based aspect of NOS, the majority of *coherent* links were with informed (28 links) and developing (five links) levels of NOS understanding, but there were also a large number of *incoherent* links with informed levels of understanding (11 links) of this NOS aspect (Table 4.18, page 187). Where the data reflected results such as the two scenarios explained here, no synopsis could be easily compiled, and the corresponding block/s in Table 5.4 were left unfilled.

The synopsis of results presented in Table 5.4 helps to unveil a number of emerging insights into the relationship between students' views of the natural world and their views of NOS. On the one hand, *green shaded blocks* indicate where clusters of themes were coherent with an informed (and developing) understanding of particular NOS aspects. As such, these are areas in which the students' views of the natural world seemed to support them holding an informed NOS understanding. Specifically, an informed understanding of the tentative aspect of NOS had coherent links with views related to *Knowing and finding out* about Nature, and knowledge that is *Unsure*. Links relating to *Sure knowledge* were coherent with an informed understanding of the role of empirical evidence in science. An informed understanding of the theory-laden[16] and socially- and culturally-embedded aspects of NOS had coherent links relating to *Interactions/transactions* with Nature and with knowledge. Views concerning *Choosing between alternative explanatory frameworks* were coherent with an informed understanding of the socially- and culturally-embedded, and imaginative and creative aspects of NOS.

On the other hand, *red shaded blocks* (Table 5.4) indicate where clusters of themes were coherent with naive (and developing) understandings of particular NOS aspects. Red blocks

[16] Naive NOS views that were incoherent with worldview statements were considered equivalent to informed NOS views that were coherent with such worldview statements.

therefore flag potentially problematic areas in regard to the relationship between students‘ views of the natural world and their views of NOS. First, there were coherent links between statements concerning *Knowing and finding out*, and a naïve understanding of the socially- and culturally-embedded, and imaginative/creative aspects of NOS—these links indicate a lack of recognition of the human element of science. Second, there were coherent links between statements concerning *Sure knowledge*, and a naïve understanding of the tentative and imaginative/creative aspects of NOS. These links indicate a lack of understanding of how scientific knowledge can be simultaneously reliable and tentative, and how we can be sure of scientific knowledge even though scientists might use their imaginations and creativity in developing such knowledge.

Overall, what Table 5.4 shows is how some clusters of themes were coherent with informed understandings of particular NOS aspects whilst also being coherent with naive understandings of other NOS aspects. For example, statements relating to *Knowing and finding out* about the natural world were coherent with informed views of the tentative aspect of NOS, whilst also being coherent with naïve views of the socially- and culturally-embedded and imaginative/creative aspects of NOS. Similarly, statements relating to *Sure knowledge* were coherent with an informed understanding of the empirically-based aspect of NOS whilst also being coherent with a naive understanding of the tentative, and imaginative/creative aspects of NOS (Table CL-2). The relationship between students‘ views of the natural world and their views of NOS is therefore a complex one, as discussed next.

Complex relationship between views of NOS and views of the natural world

The assertion regarding the complexity of the relationship between views of the natural world and views of NOS finds support not only in the data from the present study, but also in international reform and curriculum documents describing the desired view of NOS that students are to develop (e.g., AAAS, 1989, 1993; NRC, 1996; NSTA, n.d.). In the present study, the contents of international reform and curriculum documents were extracted in order to develop the analytic framework used in assessing the students‘ levels of NOS understanding (Chapter 3, page 78). The following bulleted statements have been drawn from the NOS analytic framework employed in the present study (Appendix 3.12, page 295), in order to demonstrate the complexity of the relationship between views of Nature and views of NOS. Numbered references relate to Figure 5.4, which presents a diagrammatic overview of this complex relationship.

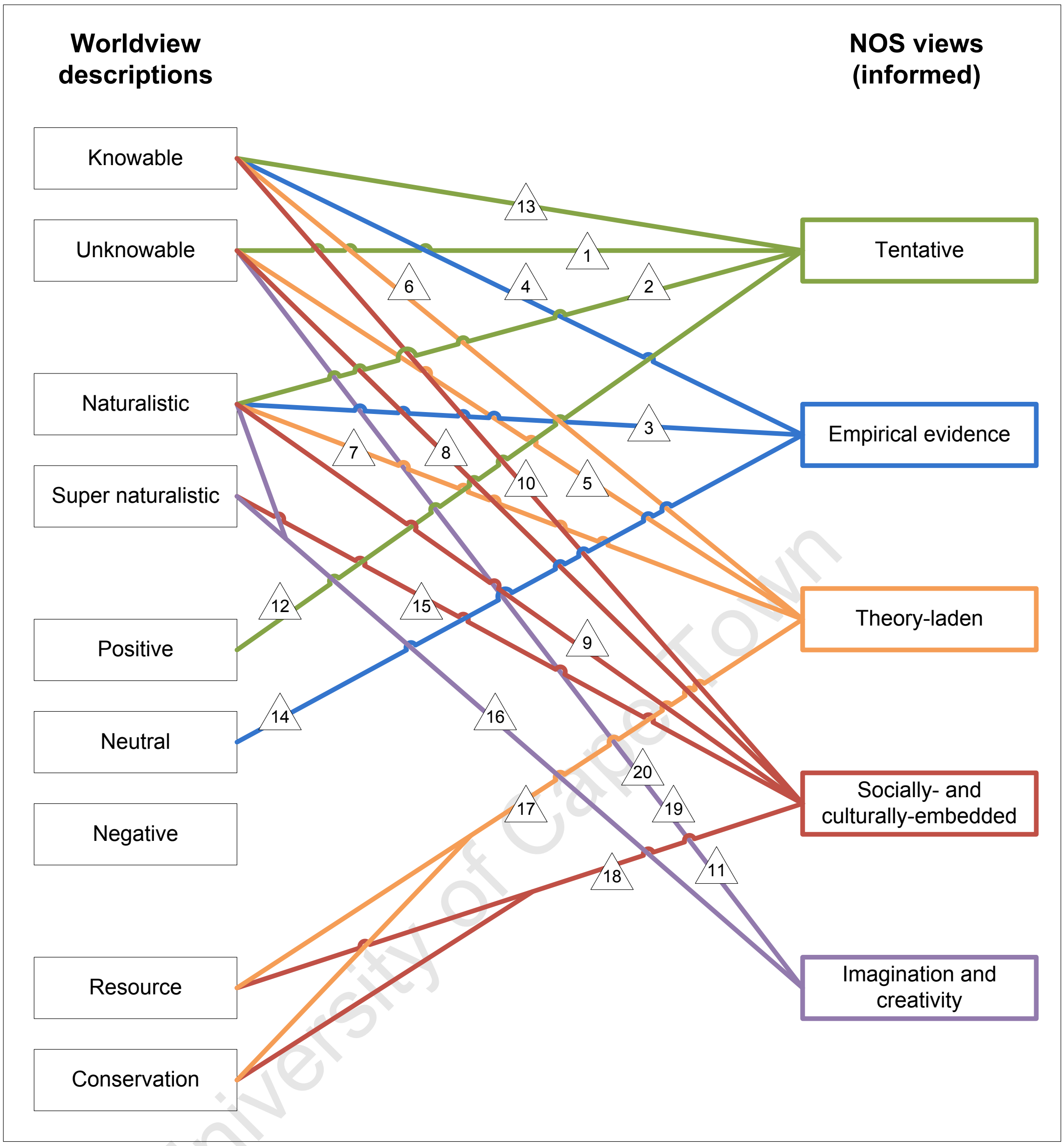


Figure 5.4: Diagram showing the complex relationship between views of the natural world and informed NOS understanding

- Scientific knowledge is tentative, in that we are never 100% sure about anything (1). Scientists might encounter new experimental evidence and change what they said before (2).
- Science is limited to naturalistic methods, and is precluded from using super-naturalistic elements in the production of scientific knowledge (3). For example, scientists use observation, exploration and experimentation (4).
- However, not all scientific knowledge has been proven. Some knowledge arises from speculation (5) and is based on theory (6). Theoretical knowledge is based on evidence that

has been collected. Observations are also theory-laden (7).

- Scientists might disagree in areas where there is not much evidence (8). They might also make different observations or interpret data differently, based on their personal experiences and expectations and their socio-cultural environments (9). Knowledge is constructed through social negotiations (10).
- Sometimes scientists need to use their imaginations and creativity to explain how data fit together (11). However, the fact that scientists use their imagination/creativity does not mean that scientific knowledge is unreliable (1).

As previously indicated, results from the present support a complexity view of the relationship between views of Nature and of NOS. In order to further illustrate this point, the following statements have been taken from data summarized in Table 5.4. Numbered references continue to relate to Figure 5.4.

- Informed views of the tentative aspect of NOS were coherent with statements relating to *Unsure knowledge*, and Naïve views of the tentative aspect of NOS were coherent with statements relating to *Sure knowledge* (1): People cannot know everything in Nature. There‘s always more to discover, so knowledge changes. Nature also changes so it is confusing, and scientists might change what they say, or they might find they made a mistake somewhere and change their minds.
- Informed views of the tentative aspect of NOS were also coherent with statements relating to *Knowing and finding out*: People have a curiosity and a need to know more about Nature (12). Scientists help us to find out more about our planet (13).
- Informed views of the empirically-based aspect of NOS were coherent with statements relating to *Sure knowledge*: Scientists know things about Nature by observing everyday phenomena 14) and studying evidence, for example by using technology and conducting experiments (4).
- Naïve views of the role of imagination and creativity in science were coherent with statements relating to *Sure knowledge* (11), and therefore, by implication, informed views of this NOS aspect would be coherent with statements concerning *Unsure knowledge*: Nature is vast and technology is limited, so people cannot see and know everything about Nature. Scientists use their imaginations and creativity in thinking about where to search for undiscovered phenomena in Nature. They might also use their imaginations/creativity, based on facts that have been found, in trying different ways to explain the data.
- Informed views of the socially-and culturally-embedded (15) and imaginative/creative aspects of NOS (16) were coherent with statements concerning alternative *explanatory*

frameworks and how to make sense of conflicts between science and religion: Scientists can‘t always work out why things happen (e.g., the Big Bang), so they sometimes need to use their imaginations to collate all the information and devise an explanation (16). There will always be different answers, and therefore scientists sometimes disagree. Various explanations could be correct (15).

- Statements relating to *Interactions/transactions* were coherent with naïve views of the theory-laden aspect of NOS (17): In some areas, scientists lack sufficient evidence, yet they are certain of their knowledge, and it is this knowledge that needs to be passed on to future generations. Statements relating to *Interactions/transactions* were also coherent with informed views of the socially-and culturally-embedded aspect of NOS (18), specifically concerning scientists inventing things: Scientists work together to develop new technology, some of which helps in the conservation and sustainable use of natural resources.

In summary, the following assertions can be made concerning the relationship between views of the natural world and views of NOS: Informed views of the tentative aspect of NOS cohere with both Knowable (13) and Unknowable (1) views of Nature, as well as being coherent with Naturalistic (2) and Positive (12) worldview descriptions. Informed views of the empirically-based aspect of NOS cohere with Knowable (4), Naturalistic (3), and Neutral (14) views of the natural world. Informed views of the theory-laden aspect of NOS cohere with both Knowable (6) and Unknowable (5) worldview descriptions, as well as being coherent with Naturalistic (7) and both Resource-oriented and Conservationist (17) views of the natural world. Informed views of the socially- and culturally-embedded aspect of NOS cohere with views of Nature that are both Knowable (10) and Unknowable (8), as well as being coherent with worldview descriptions that are both Naturalistic (9, 15) and Super naturalistic (15), and both Resource-oriented and Conservationist (18). Informed views of the role of imagination and creativity in science cohere with views of the natural world that are Unknowable (11, 19, 20) and both Naturalistic and Super naturalistic (16). The relationship between views of the natural world and views of NOS is thus a complex one, and this holds implications for science teachers.

In helping students to develop more informed NOS views, it is recommended that science teachers present to them a full complexity view of both the natural world and of NOS, as well as making explicit the complex relationship between the two domains. For example, it can be argued that the nature of science reflects what the natural world is like (Alexakos, 2010). Therefore, just as the nature of science is tentative and includes some speculation, so the natural world is also changing and some elements of Nature remain unknown (Alexakos, 2010). Moreover, as mentioned earlier, the data revealed links between students‘ views of NOS and of Nature that were potentially problematic, and these links signal particular understandings that teachers need to addressed with students. For example, students need to recognize that science is a human endeavour (19, 20) (i.e., understanding the role of imagination/creativity and scientists‘ personal experiences and expectations in science, and recognising that scientists work within particular social and cultural contexts). Teachers also need to explain to students what it means to be certain in science, whilst recognizing the human element in science, and that scientific knowledge is subject to change.

Further issues arising from particular links between the students‘ statements about Nature and about NOS are presented next.

Links between worldview descriptions and levels of NOS understanding: Issues arising from themes

A complexity view of the relationship between views of the natural world and NOS views, helps to shed light on the links that were established between the 15 themes and views concerning particular NOS aspects. Potential difficulties are apparent from the complex interplay between views of the natural world and understanding about NOS. However, there remains a need to try to understand why students‘ NOS views are typically naive, and to gain more detailed insight into how students‘ views of the natural world might be related to the NOS views that they hold. Therefore, a focussed analysis was conducted of the coherent links between students‘ naive NOS views and their views of the natural world, and incoherent links between students‘ informed NOS views and their views of the natural world (Chapter 4, page 189). This focussed analysis revealed a number of issues that need to be addressed in science classrooms, in order to help students with various conceptualisations of Nature to develop a more informed understanding of NOS. These various issues were related to twelve topics, namely, (1) the role/purpose of science, (2) natural diversity and patterns in Nature, (3) the nature of scientists‘ work, (4) the limits to our knowledge of the natural world, (5) the ability to make predictions about Nature, (6) making sense of uncertainties, intangibles and a lack of evidence in science, (7) the reliability of scientific knowledge, (8) truth and proof, (9) the relationship between empirical evidence and scientists‘ own ideas and imaginations, (10) the relationship between imagination/creativity and mis-information, (11) disagreements amongst scientists, as well as issues relating to (12) alternative knowledge frameworks/domains.

Implications of issues in regard to students' NOS views

The issues identified above hold implications for science teachers in their attempts to improve students‘ understanding about each of the five target aspects of NOS. For example, students‘ views concerning how much we know of the world, the need to study Nature, passing on knowledge to future generations, and dealing with predictions of negative future natural events, may influence their views of the tentative aspect of NOS. Second, students‘ understanding regarding the empirically-based aspect of NOS may be influenced by their views regarding how exactly scientists go about their work and what it is that scientists study, whether Nature is predictable, the reliability of scientific knowledge in lieu of scientists sometimes making mistakes, the relationship between knowledge about the natural world and enjoyment of Nature, and what constitutes the boundaries of science as an explanatory framework and how this relates to people‘s personal beliefs. Third, students‘ understanding regarding the theory-laden aspect of NOS might be influenced by their views regarding the role and purpose of science, how to make sense of scientific knowledge for which there is insufficient or partial evidence and associated feelings of uncertainty, how to make sense of scientific predictions and forecasts, as well as the reliability of scientific knowledge vis-à-vis science as a human endeavour, errors, and conflicts with personal religious beliefs. Fourth, students‘ understanding regarding the socially- and culturally-embedded aspect of NOS might be influenced by their views regarding how much of Nature can be known and understood, how to make sense of scientific knowledge that is uncertain, the relationship between empirical evidence and scientists‘ own ideas, the possibility of multiple valid answers in science, and the causes and resolution of disagreements amongst scientists. Finally, students‘ understanding regarding the role of imagination and creativity in the development of scientific knowledge may be influenced by their views concerning the purpose of science, understanding concerning truth and proof, the interplay between scientists‘ use of imagination and the use of empirical evidence in science, how forecasts and predictions are made in science, and importantly, what it means to use imagination in the context of science and how this differs from fiction and deceitfulness.

The above discussion has focussed on emerging insights obtained from analyses of the interplay between students‘ views of the natural world and their views of NOS. What follows next is a discussion of the coherence of the students‘ views overall.

Overall coherence of the students' views

The results of the present study show that none of the students' views were completely coherent overall. In each case, there were instances of varying combinations of complexity and incoherence within students' views of the natural world and/or within their NOS views, incoherent links between their views of the natural world and their NOS views, as well as instances of explicit conflict or compromise views. This lack of overall coherence of the students' views is in contradiction with a coherence view of knowledge (Cobern, 1994; P.W. Hewson, 1982, M.G. Hewson & Hewson, 1989) which advocates that in the aim of maintaining internal consistency/coherence within their conceptual frameworks, students will resist acquiring new knowledge if it conflicts with their existing views (P. Bloom & Weisberg, 2007). One therefore needs to consider how it is possible to find that the students' views were only somewhat coherent.

During the course of learning, students begin to see the world differently than before (Cobern, 1994), as they experience changes to their fundamental beliefs and understandings about the world (Posner et al., 1982). As such, learning can be viewed as a process of identity-formation (Hansson & Redfors, 2007b; Hansson & Lindahl, 2010). The worldviews and identities of people are not fixed (Cumpsty, 1991; De Wet, 2000). It is possible, therefore, that the lack of internal coherence within the students' conceptual frameworks occurred because their ideas are not yet fully formed at this age (11-12 years) and grade level (Grade Six), and because their identities are still developing. In support of this assertion, it emerged during the data collection process that opportunities to think about and articulate explicitly their ideas about the natural world and about the nature of science were rare—if not unique—for the students. Their feedback regarding their experiences of participating in the study, indicated that, during the interview process, they felt they had gained new knowledge and understanding (Appendix 5.1, page 429). There seems to be potential, therefore, for Grade Six students' views to continue to develop. The development of students' identities when learning, specifically with regard to how students define themselves in relation to Nature, constitutes a key question in science education (Allen & Crawley, 1998). Studying the views of students from older age groups, or examining changes in students' conceptions of Nature, constitute possible avenues for future research.

Lack of coherence within the students' conceptual frameworks could also be a reflection of the inherent complexity of views regarding the natural world and what constitutes an informed understanding of the nature of science, as well as of the complexity of the interplay between concepts in these two domains. These complexities have implications for the way in which concepts are presented to students in science classroom, specifically concerning what views of the natural world are (or are not) presented to students, how ideas about NOS views are presented, how ideas about science relate to views of the natural world, as well as how apparent contradictions between science content and religious teachings are addressed and can be managed successfully. The issue of managing contradictory views has been discussed earlier (page 243).

Evidence of students' attempts to manage apparent contradictions supports Robson's (2006) notion that during the process of learning, individuals strive to maintain equilibrium between their existing cognitive schemas and new concepts within their conceptual frameworks. However, it has also been suggested that we can all live with large amounts of cognitive dissonance, and that there is no reason to require that individuals have an entirely—or even largely—logically coherent view of the world (El-Hani & Sepulveda, 2010). Indeed, the students in the present study seemed largely unaware of a number of the instances of system complexity and system incoherence that were identified during the analysis of their worldview and NOS statements, as well as being unaware of the existence of incoherent links between their descriptions of the natural world and their NOS statements. However, an apparent lack of awareness does not necessarily imply that conceptual framework incongruities are unproblematic for students. Some specific conflicts between their views of Nature and NOS views were articulated explicitly by the students, and they employed various strategies in attempting to manage such conflicts (Chapter 4, page 194). The description of compromise views in some cases, as well as evidence of the use of various collateral learning strategies, seems to indicate students' desire to manage cognitive conflicts in some way.

In fact, instances of cognitive dissonance (cognitive conflict) (M.G. Hewson & Hewson, 1989; Posner et al., 1982; Robson, 2006) can be used productively to stimulate reflection and debate in the classroom, encouraging students to think about and discuss particular issues and concepts, in the process of developing coherent conceptual frameworks. For example, cognitive conflict could be employed in address specific issues related to worldview and to NOS views, and the relationship between the two sets of views.

In the present study, instances of system complexity and system incoherence, and incoherent links between views of Nature and views of NOS were not pointed out to the students. This was because the focus of the study was on eliciting and analysing the views that students described, and not on attempting to influence their current views in any way (e.g., by alerting them to apparent inconsistencies). However, in the science classroom, instances of apparent incoherence or complexity, within or between students' views of the natural world and their NOS views could serve as an effective catalyst for reflection and discussion regarding a number of important issues pertaining to Nature, NOS and the relationship between the two. Analysis of the impact of such intervention constitutes a meaningful avenue for further research (i.e., how students respond when apparent instances of incoherence within their conceptual frameworks are revealed to them).

Another aspect to consider in this discussion of the overall coherence of students' views, pertains to the correlations that were found amongst the incoherent links between students' views of the natural world and their views of NOS views, and the various instances of system complexity and system incoherence that existed within each of these two domains (Chapter 4, page 205). For example, there were incoherent links relating to the theme *Search, explore, and observe*, concerning people searching for evidence, and exploring places and observing things in Nature (Table 4.24, page 206). Similarly, within students' epistemological worldview descriptions there were instances of system incoherence concerning how people find out about the natural world (Table 4.24, page 206). There was also an instance of system incoherence within a student's NOS views concerning how scientists go about their work (Table 4.24, page 207). The possible relationship between complexities/incoherence *within* students' views of Nature and NOS and incoherent links *between* these two domains, holds implications for science teachers and science education researchers.

As previously mentioned (page 261), it has been suggested that students' conceptual frameworks strive towards internal consistency or coherence (e.g., P. Bloom & Weisberg, 2007; Cobern, 1994; P.W. Hewson, 1982; M.G. Hewson & Hewson, 1989). Therefore, students will resist acquiring new knowledge if it conflicts with their existing views about the world (P. Bloom & Weisberg, 2007; Cobern, 1994; P.W. Hewson; 1982, M.G. Hewson & Hewson, 1989). Students' current beliefs and views about what the world play an important role in learning, by influencing how new concepts are related to and incorporated into students' existing conceptual frameworks (e.g., Carey, 2000; Cobern, 1994; P.W. Hewson, 1982; Posner et al., 1982). Consequently, improving the internal consistency of student's views of the natural world and views of NOS, respectively, might help to improve the coherence between these two domains. Moreover, improving the coherence between students' views of Nature and of NOS might contribute towards them holding a more informed understanding about NOS. Possible avenues for further research therefore concern the following two questions: To what extent does improved internal consistency within students' views of the natural world and within their

NOS views contribute towards increased coherence between these two domains?, and, What is the impact of this increased coherence on students' levels of NOS understanding?

The last section of this chapter involves a discussion of the value of employing explanatory coherence principles when analysing coherence between views of the natural world and views of NOS.

Application and usefulness of explanatory coherence principles

It is difficult to determine the relationship between students' descriptions of the natural world and their understanding of NOS by simply comparing students' views relating to each domain. Rather, a structured and systematic approach is required in order to carry out a detailed analysis of these data. However, due to the paucity of research to date in this specific area, no such existing analytic framework could be found. Therefore, an exploratory approach was employed in this study, whereby principles of explanatory coherence (see Thagard, 1989, 1992, 1994, 2006) were applied in establishing specific links between students' NOS statements and their statements about the natural world. Explanatory coherence principles were also applied in the analysis of coherence within students' views of NOS and their views of the natural world, respectively (Chapter 3, page 100).

What follows is a discussion concerning the value of employing explanatory coherence principles in analysing the relationship between views of the natural world and views of NOS.

In the present study, employing various principles of explanatory coherence provided structure and focus to the analysis by highlighting the kinds of ways in which the students' statements might agree or conflict with one another. That is, coherent links could be identified when a statement was supported by an illustration or example, or when two statements agreed with each other. Similarly, for incoherent links, two statements might have conflicted with each other, or an illustration or example might have conflicted with another statement. It was therefore possible to record specific instances of coherence and incoherence, and to provide evidence and illustrations to support assertions about the relationship between students' views of the natural world and their views of NOS. Further in-depth data analyses across the multiple cases could then be conducted, for example, identifying themes and patterns amongst the various links. Importantly, particular issues of complexity that arose for the students could be identified, and recommendations for science teachers could be made accordingly. Moreover, these particular issues highlighted the complex interplay between views of the natural world and views of NOS, and the need for further research to be done.

In addition to seeking evidence of coherence and incoherence *between* a student‗s statements about the natural world and about NOS, applying the explanatory coherence principle of system incoherence alerted the researcher to a need also to identify instances of incoherence *within* a set of views. However, it was not sufficient to apply only the principle of system incoherence in analysing such internal coherence. This is because in some cases it was found that within a student‗s views there were inconsistencies or complexities that were not strongly opposed enough to be regarded as instances of system incoherence. Accordingly, an additional principle was derived from the principle of system incoherence, namely, system complexity (Chapter 3, page 100). Applying the principle of system complexity made it possible to reflect finer variations of inconsistencies and complexities within a set of views, and to draw out students‗ descriptions of border-crossing experiences that were related to explicit conflicts and compromise views (Chapter 4, page 170 and page 194). Instances of system complexity within individuals‗ statements about Nature and about NOS drew attention to the inherent complexity of the concepts of what is Nature and what is the nature or science. Furthermore, instances of system complexity and system incoherence within the students‗ views could also be related to incoherent links between students‗ views belonging to these two domains (Chapter 4, page 205).

Due to a lack of existing methodology for exploring the relationship between NOS and worldviews, the use of explanatory coherence principles was an approach borrowed from previous research investigating coherence of students‗ understanding of science content matter (e.g., concepts about force). The results of the present study show that explanatory coherence principles can also be applied to analyses of what Duit and Treagust (2003) refer to as conceptions at meta-levels—that is students‗ conceptions of what Nature is and how we come to know things about the natural world, and students‗ conceptions of NOS and how scientific knowledge is produced. Explanatory coherence theory (Thagard, 1992) can also be used to examine changes in students‗ conceptions, for example, by confronting students with apparent inconsistencies within and/or between their articulated views. Exploring changes in students‗ views was beyond the scope of the present study (Chapter 1, page 7), but constitutes a possible avenue for further research.

In summary, the explanatory coherence principles employed in the present study provided structure and focus for the data analyses, and enabled a systematic and comprehensive exploration of coherence within and between students‘ views of Nature and of NOS. Detailed and in-depth data included evidence of specific links that were established. Further analysis of these coherence data involved the identification of themes amongst the various links, and highlighted the complexities inherent in the concepts of NOS and Nature, and the complex relationship between these two domains. Specific issues could be identified that science teachers are advised to address with their students, and avenues for future research could be suggested. As such, explanatory coherence principles served as a useful tool for analysing the relationship between students‘ views of the natural world and their NOS views, as well as for examining the overall coherence of students‘ views.

In response to the third research sub-question, this third part of the discussion has focussed on the results concerning the coherence of students‘ views of the natural world and their views of NOS. To begin with, coherence between students‘ definitions of Nature and their views of the work of scientists was presented. This was followed by a discussion highlighting the complexity of the relationship between views of the natural world and views of NOS. A number of issues were then outlined, which need to be addressed with in science classrooms, and which arose from particular coherent and incoherent links between the students‘ views of Nature and of NOS. The discussion proceeded with an examination of the extent to which the students‘ views were coherent overall, and ended with reflective comments concerning the application of explanatory coherence principles in conducting an analysis of coherence. The significance of the study and recommendations for future research are presented in the next two sections, followed by concluding remarks.

Contributions of the study

The present study contributes to knowledge in science education by: 1) providing in-depth insights into students‘ views of NOS and of Nature, and into the coherence of students‘ views relating to these two domains, 2) developing and applying novel research methodologies, 3) making recommendations for teaching practice, and 4) identifying possibly productive avenues for future research. These contributions are particularly valuable in lieu of the paucity of research that has been conducted concerning elementary students‘ views of Nature and of NOS, and concerning the relationship between these two domains—especially within the South African context.

Addition of new knowledge

Regarding NOS, a number of themes of responses were identified amongst the statements of the students, pertaining to various levels of NOS understanding. NOS data provided further evidence of the richness within, and diversity amongst, individuals‘ NOS views. Regarding views of the natural world, a wide range of student responses was presented. Worldview data also revealed the richness within, and subtle variations amongst, the views of Nature described by the students. Regarding coherence, data analyses revealed complexities and instances of incoherence and conflicts within the students‘ views. A number of coherent and incoherent links were also established between students‘ views of NOS and their views of Nature. Particular issues arising from these various instances of complexity and incoherence were presented. This study therefore provides detailed insights into selected Grade Six students‘ views of NOS and of Nature, as well as providing evidence of the complex relationship between these two domains.

Development and application of novel research methodologies

During the collection of the NOS data, a novel methodology involved providing opportunities for students to review their responses to the *VNOS-rs* questionnaire with the researcher immediately after completing this written task. Regarding the worldview data, a novel analytic approach involved the design of continua to record the finer details of students‘ descriptions of the natural world. Profiles of the students‘ views of NOS and their views of Nature were also presented. Due to a lack of established methodology for analysing the relationship between NOS views and worldviews, a novel analytic strategy was explored, which involved the application of explanatory coherence principles. To this end, an additional explanatory coherence principle, system complexity, was also devised and employed.

Discussion of recommendations for practice & opportunities for further research

Recommendations arising from the findings in the present study, aimed at science education researchers, are related to methodologies for improving the procedures for collecting and analysing detailed and accurate data of students‘ views of NOS and of the natural world. Recommendations for science teachers concern a need to address students‘ limited views relating to NOS and to Nature, to discuss with students the inherent complexity of these two concepts, as well as to reflect upon and discuss particular coherence issues that arise from the complex relationship between these two domains. A more detailed summary of the implications and recommendations arising from the results of the present study is presented in Appendix 5.2 (page 430).

Possible avenues for future research pertaining to NOS relate to investigating the effect of employing context-specific—rather than generic—questions when eliciting students‘ views of

NOS, examining how students' views of the various aspects of NOS develop in relation to one another, and exploring the development of students' NOS profiles for use by science teachers. Possibilities for future studies concerning students' views of the natural world, relate to the application and usefulness of a series of continua in recording and analysing individuals' views of Nature. Analysing the relationship between students' epistemological worldview descriptions and their academic abilities, exploring changes in individual's conceptualisations of Nature as students mature in age, studying the relationship between students' epistemological worldview descriptions and the image of Nature presented to them in the science classroom, and probing possible differences between students' declarative knowledge and their personal knowledge, constitute four additional avenues for future research concerning worldviews.

Regarding coherence, possible avenues for further research involve exploring changes in students' views when they are confronted with apparent consistencies within and/or between the views they articulate, analysing the extent to which improved internal consistency within students' views of NOS and of Nature contributes towards increased coherence between these two domains, and investigating the impact of improved coherence of students' views on their levels of understanding about NOS.

Concluding remarks

This study was designed to explore the coherence of Grade Six students' views of NOS and their views of the natural world. Little research has focussed on the NOS views of elementary school students, and particularly in a South African context. Moreover, very little is known about the relationship between NOS and worldview (and in particular, the component of worldview concerning views of the natural world), and consequently there is no established methodology for exploring this relationship. This study therefore contributes to existing knowledge in science education on a number of levels. To begin with, in-depth data were provided concerning the students' views of NOS and of Nature. These data further revealed the inherent complexity of what constitutes an informed understanding of NOS, and the inherent complexity of the concept of Nature. Moreover, a novel methodology was employed in exploring the coherence of these two domains. Results of the analyses of coherence highlighted the complex relationship that exists between students' views of Nature and their levels of understanding about NOS. Implications and recommendations have been discussed, for both science education researchers and science teachers, and possible avenues for further research have been identified.

Although the present study was an exploratory investigation, it sheds some light on the important and yet relatively unexplored area of research concerning the relationship between views of NOS and views of the natural world. A greater understanding of the relationship between students‘ NOS views and their worldviews (and in particular, their views of the natural world), can help to inform teaching practices in which science knowledge is more meaningfully related to students‘ everyday thinking. Moreover, a greater understanding of the coherence of views about NOS and Nature, can contribute towards improving students‘ levels of understanding about NOS. Helping students to develop informed NOS views constitutes an important component of scientifically literacy, which is one of the major goals of science education.

Appendix 3.1
PERMISSION FROM WCED TO CONDUCT RESEARCH IN SCHOOLS

Navrae
Enquiries **Dr RS Cornelissen**
IMibuzo

Telefoon
Telephone **(021) 467-2286**
IFoni

Faks
Fax **(021) 425-7445**
IFeksi

Verwysing **20070301-0007**
Reference **20070425-0019**
ISalathiso

Wes-Kaap Onderwysdepartement

Western Cape Education Department

ISebe leMfundo leNtshona Koloni

Mrs Robyn Sokolinski
School of Education
University of Cape Town
RONDEBOSCH, 7700

Dear Mrs R. Sokolinski

RESEARCH PROPOSAL: EXPLORING COHERENCE BETWEEN GRADE SIX STUDENTS' VIEWS OF THE NATURE OF SCIENCE (NOS) AND THEIR VIEWS OF THE NATURAL WORLD: A SOUTH AFRICAN STUDY

Your application to conduct the above-mentioned research in schools in the Western Cape has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educators' programmes are not to be interrupted.
5. The Study is to be conducted from **5th March 2007 to 30th March 2007** (pilot study) and from **26th April 2007 to 21st September 2007** (final data collection).
6. No research can be conducted during the fourth term as schools are preparing and finalizing syllabi for examinations (October to December 2007).
7. Should you wish to extend the period of your survey, please contact Dr R. Cornelissen at the contact numbers above quoting the reference numbers.
8. A photocopy of this letter is submitted to the Principal where the intended research is to be conducted.
9. Your research will be limited to the following schools: [redacted].
10. A brief summary of the content, findings and recommendations is provided to the Director: Education Research.
11. The Department receives a copy of the completed report/dissertation/thesis addressed to:

    The Director: Education Research
    Western Cape Education Department
    Private Bag X9114
    CAPE TOWN, 8000

We wish you success in your research.
Kind regards.

Signed: Ronald S. Cornelissen
for: **HEAD: EDUCATION**
DATE: 1st March 2007

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Appendix 3.2
LETTER SENT TO SCHOOL PRINCIPALS REQUESTING PERMISSION TO CONDUCT RESEARCH INVOLVING GRADE SIX STUDENTS AT THE SCHOOL

UNIVERSITY OF CAPE TOWN

School of Education
University of Cape Town
Ph: 082 422 4543
Fax: (021) 413 1163
Email: robynsokolinski@gmail.com

[Date]

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH WITH GRADE SIXES ([DATE])

Dear [principal's name],

I am currently doing doctoral research in education at UCT, focussing specifically on primary science education. My study aims to investigate the coherence between children's views of the nature of science and their views of the natural world. I would like to include Grade Six learners from [school's name] in my study. I hereby request your permission to meet with your Grade Six classes and select approximately ten learners to participate in my research study.

The study will be carried out over a period of three to four weeks, working with only three children at a time per week. This makes the process more immediate and meaningful for each participating child. More specifically, the study entails the following:

Day 1	Meet the Grade Six classes, introduce myself and my study, and give to each willing child a letter of consent for their parents to sign and return to school.
Day 3	An initial 15 minute written questionnaire, administered to each Grade Six class.

Approximately ten Grade Six learners (working with three children per week) will then be selected to participate as follows:

Day 3*	A written questionnaire, completed individually but simultaneously by the first set of three children. This will require no longer than an hour in total.
Day 4*	An activity-based interview, conducted individually with each learner, which requires approximately one hour per child.
Day 11*	A short follow-up interview with each of the four learners, which requires approximately 20 minutes per child.

** This procedure is repeated with each set of three learners until all selected participants have been included.*

The children's responses will remain confidential and the school will also not be identifiable in any way from the results of my study. I will happily send you a copy of my questionnaires and interview schedule should you wish to see these.

With your permission I'd like to commence my study in the beginning of the third term, that is, from the middle of July. Should you agree in principle, I can contact you closer to the time in order to discuss finer details of timing etc. Please feel free to contact me should you have any queries. Thank you. I look forward to hearing from you.

Yours sincerely,

Robyn Sokolinski

Appendix 3.3
LETTER SENT TO PARENTS REQUESTING WRITTEN CONSENT FOR THEIR CHILD TO PARTICIPATE IN THE STUDY

UNIVERSITY OF CAPE TOWN

[Date]

RE: INVITATION TO PARTICIPATE IN RESEARCH IN TERMS 2-3

Dear Grade Six parent,

I am currently doing doctoral research in education at UCT, and [principal‘s name] has kindly granted me permission to include some of the Grade Sixes at [school‘s name] in my study. My study is in the field of science education, with a specific focus on primary school science. I would be most grateful if you would agree to your child taking part in my study, which will begin next week.

What does it entail? By way of introduction I shall ask the Grade Sixes to complete a short worksheet that will help me to get to know them a bit. I‘ll then select approximately ten children from the grade to continue working with me. It will involve them completing a written questionnaire (approx. 30 minutes, plus additional time for discussion afterwards), and on a separate day, I will conduct an activity-based interview with individual children (max. 60 minutes). A very brief follow-up interview (max. 15 minutes) will conclude my study.

Your child‘s responses will remain confidential and the school will also not be identifiable in any way from the results of the study. What is more, the activities will be scheduled so as to minimise possible disruptions to the normal school timetable. The children who have participated so far have really enjoyed working with me, and they said they valued the opportunity it gave them to think about different things. I think your child will find it interesting too, and I would really appreciate his/her willingness to participate.

Please complete the section below by printing your child‘s name, class and the date, and adding your signature. Then send this letter to school with him/her by Tuesday next week. I‘ll happily answer any questions you might have, and I can be contacted on 0824224543 or robynsokolinski@gmail.com. Many thanks.

Yours sincerely,

Robyn Sokolinski

CHILD‘S NAME AND SURNAME: …………………………………………………………………

CLASS : …………………………. DATE : ………/………/………….

PARENT‘S SIGNATURE : ………………………………

Appendix 3.4
FOLLOW-UP LETTER SENT TO PARENTS CONFIRMING THEIR CHILD'S SELECTION FOR PARTICIPATION IN THE STUDY

UNIVERSITY OF CAPE TOWN

[Date]

RE: SELECTION FOR PARTICIPATION IN RESEARCH STUDY

Dear Grade Six parent,

Thank you for agreeing to your child's participation in my doctoral study. I really appreciate your support in this regard, and shall begin working this week.

Having selected a few children from the Grade Sixes, they will be grouped into sets of three so that I can work with one set (i.e., three children) at a time. In working like this, your child's time with me will not be spread out over too long a period of time, so s/he can receive more immediate feedback and follow-up. The process becomes more meaningful for her/him in this way.

I remind you that your child's participation remains voluntary and I assure you that her/his responses will be kept confidential at all times. I'm really looking forward to working with this group of children.

Should you have any questions, please do not hesitate to contact me on (mobile phone) 0824224543 or (email) robynsokolinski@gmail.com.

Again, many thanks for your support.

Yours sincerely,

Robyn Sokolinski

Appendix 3.5
INTERVIEW SCHEDULE REGARDING THE SCHOOL'S RELIGIOUS POLICY

Name of school:	
Person interviewed:	
Date of interview:	

1. What is the religious affiliation of the school?

....

2.a. Does the school have a specific religious policy? YES / NO

2.b. If yes, please describe it briefly to me:

....
....
....
....

2.c. *And*, if yes, please can I have a copy of this document?

....

2.d. How is religion/the school's religious policy played out at school? *or*
In what ways is this religion practised at school?
e.g., school assembly meetings, dedicated lessons, extra-mural activities, etc.

....
....
....
....
....
....

2.e. How much time is allocated per week to these activities?

....
....

3. What is the religious background of most of the pupils at this school?

....
....

4. Additional notes:

....
....
....
....
....
....

Appendix 3.6
DESCRIPTIONS OF EVIDENCE OF THE RELIGIOUS AFFILIATIONS OF THE THREE PARTICIPATING SCHOOLS

As previously mentioned, the schools included in the sample were carefully selected in order to study children with diverse worldviews. Religion, as a dominant cultural marker, was used as an indicator of cultural diversity, and schools affiliated to the three Abrahamic religions were sought, namely, a Christian school, a Muslim school, and a Jewish school. What follows is a summary of the evidence obtained confirming the religious affiliation of each of the participating schools.

School C (Christian)

The principal of School C identified this school as one of four Anglican[17] schools in Cape Town, and furthermore, as the only co-educational school of the four Anglican schools he mentioned. School C was described as being Anglican-based, and the principal said that the school was attended by a number of children of Anglican bishops ―as they get special dispensation" to go there. The school was also attended by children from religions other than Christianity. Chapel services were held at the school, and these services were led by school chaplains. Divinity lessons, that is, Christian Bible Education Lessons, had previously been included in the weekly teaching timetable at the school, but these had been discontinued during the previous year as ―the children get enough input from chapel meetings and hymns, and from Life Orientation lessons. That said, however, the Divinity lessons had been replaced by Life Orientation lessons, which included teaching about Life Skills and Religion (including teachings about Christianity and other world religions).

School J (Jewish)

School J was ―a Jewish Day School" (*Parent Guide*, 2006/7, p.1), and according to the latest *Parent Guide* document, the school's mission statement was ―to provide the best possible Judaic, secular, cultural and sports education for Jewish children in order to foster their Jewish identity and to enhance their potential, within both the Jewish and wider community" (p.1). The *Parent* Guide went on to describe the following regarding the school's religious policy: ―Doctrinally, the school's religious teaching is orthodox, but children of all shades of religious persuasion are accepted, including non-Jewish children. Prayer services are held daily and all Jewish festivals and holy days are celebrated and commemorated[18]…The State of Israel, as the

[17] Believers in *Anglicanism* form part of a greater body of religious believers who are Christian.
[18] A list of Jewish festivals and fasts for the year was included later in the document (p.35).

historic and spiritual home of the Jewish people, is central to the school‘s teaching. Hebrew and Jewish Studies are compulsory subjects.” Indeed, the Grade Six timetable included 4.5 hours of Hebrew and 4 hours of Jewish Studies lessons every week. Jewish History was also offered as a learning subject for Grades Four to Six. Co-curricular activities offered by the school included a *Batmitzvah Club* and *Extra Hebrew* lessons (*Parent Guide*, 2006/7, pp.16,24).

In addition to the above, School J offered an ―Extended Judiaca Programme” (Parent Guide, 2006/7, page 16), which included ―Torah Time” (regular meetings before school, when students could engage in ―deeper levels of explanation and discussion about various aspects, such as prayer, the portion of the week, and the Ethics of the Fathers”) and ―a varied and vibrant *Batmitzvah programme*” (offered to the Grade Six girls once a week, whilst boys spend time discussing issues related to their *Barmitzvahs.*[19]

At School C, the rules were ―based on Jewish values” (*Parent Guide*, 2006/7, p.9), including adherence to a *Kashrut*[20] policy (that is, all food consumed at school was strictly *Kosher*[3] (*Parent Guide*, 2006/7, pp.9,37). Further evidence of the school‘s religious affiliation was observed in the form of dress code (i.e., the boys typically wore a traditional Jewish head covering, known variously as a *yarmulka*, *skullcap*, or *kipot*), religious artefacts in the school buildings (i.e., there was a *mezuzah*[21] affixed to each doorframe), and religious ceremony (i.e., freshly baked *challah* bread was ordered from the nearby *Shul* and delivered to the school every Friday: in each class the children then broke the bread together in celebration of *Shabbat* [i.e., the Jewish Sabbath]).

School M (Muslim)

The principal of School M described the school as an Islamic school, which aimed to train children as ―leaders in the community” with a ―good moral upbringing”. The religious background of most of the students was Muslim. In the classrooms, every day began with prayer. This was followed by five minutes spent reading from the Qur'an (i.e., the sacred book of Islam), including the opening verse of the Qu‘ran and various other *suras* (chapters) from

[19] *Bat mitzvah* is the name of the Jewish ceremony for Jewish girls aged 12 or 13 years, which recognises the girl as an adult who is responsible for her moral and religious duties. *Bar mitzvah* is the name of the Jewish ceremony performed by 13-year-old Jewish boys.

[20] *Kashrut* refers to Jewish dietary law. *Kosher* food is considered fit for consumption by Jews according to traditional Jewish law. A list of Kosher food products was included in the *Parent Guide* (pages 37-42).

[21] A cylindrical holder containing a prayer or blessing, believed to bring long life and protection. The *mezuzah* was kissed or touched every time a person passed through a doorway at the school.

“the heart of the Qur'an”. Students read these scriptures regularly in order to memorise them. School assembly meetings were with all the students twice a week, and these meetings included a “moral story”, “chanting and praising”, and prayers. In addition to the above, Islamic Studies was included as an academic subject at the school, which was taught three to four times a week (i.e., 1 ½ to 2 hours) to the upper elementary students, and five times a week for students in the younger grades. Islamic Studies included the study of Islamic history, moral training, essentials and practices, jurisprudence and daily practices for a good life. The Islamic Studies teacher served as a mentor and counselor to students at the school, thereby offering them additional support and guidance whilst reinforcing the religious teachings of Islam. In addition to daily prayers and readings, school assembly meetings, and formal Islamic Studies in the teaching timetable, an additional three hours a week were spent in proper recitation from the Qur'an. Moreover, when interviewed, the school principal mentioned that there were two Grade Six boys who spent all day in the mosque preparing to become a *Hafiz*[22]. Apart from being mainstreamed for certain school subjects such as Mathematics, these two boys spent their days memorising the *Qur'an* and its translations. Further evidence of the school‘s religious affiliation was found in the dress code. According to Edis (2009:897), “the dress code of women is the most visible marker of difference between traditional a nd more secular people” in Islam. At school M, in accordance with their religious beliefs, all of the female staff and students wore loose-fitting, full-length garments, including headscarves to cover their hair. Male staff members wore modest, loose-fitting, ankle-length garments, and both the adult men and the boys typically wore a *kufi* hat on their heads. Throughout the school, staff and students greeted one another with a greeting common among Muslims: “Assalamu alaikum” (Peace and tranquillity be upon you and may *Allah* protect you) and “Wa Alaikum as-Salam” (And upon you be peace).

[22] *Hafiz* is a term used by Muslims for those believers who have completely memorised the *Qur'an*. It is the students (boys) themselves who volunteer to follow this special programme, or it is as a result of their parents‘ request.

Appendix 3.7
INTERVIEW SCHEDULE CONCERNING THE SCIENCE—AND NOS TEACHING AT EACH SCHOOL

NAME:	DATE:	SCHOOL:
POSITION HELD AT THE SCHOOL:		

1. What science **curriculum/syllabus** is taught at the school? ……………………………………………………………………………………..

2. How much **time** is spent teaching science each week? ……………………………………………………………………………………..

3. How **pressurised** is the syllabus in terms of available teaching time? i.e., Is there enough time to cover all the necessary work?
……..

4. **Who** teaches science – is it the general class teacher or a subject specialist? ………………………………………………………………….

5. **How** is science taught at the school? i.e., What is the **school's approach/policy** (if any) to teaching science?
……..
……..

6. **Where** does the science teaching usually take place? (i.e., in the Grade 6 classroom, in specialised science laboratories, etc)
……..

7. What **ideas-about-science** are taught at the school? (not referring to science content matter such as plants, phases of matter, etc.). In other words, what is being taught regarding the nature of science? Importantly, are these ideas taught **explicitly**?
……..
……..
……………………………………………………………………………………………………….Is the teaching *explicit*? YES/NO
[If the answer is YES to Question 7, proceed to Questions 8 & 9; If the answer is NO to Question 7, proceed too Question 10.]

8. For example, what ideas (if any) are taught *explicitly* regarding the nature of science: (In which grade/s is it/are they taught? How?):

Nature of science ideas	*Grade 4*	*Grade 5*	*Grade 6*	*Grade 7*
The **role of science** in society				
The nature of the scientific enterprise (i.e., what it is that **scientists do** and how they **go about their work**)				
Science as a **way of knowing**				
The **values and beliefs** inherent to **scientific knowledge** and its **development**				

9. More **specifically**, are any of the following ideas taught regarding the nature of science? If so, **how** are these ideas taught?

NOS aspect	*Tick if YES*	*How is it taught?*
Scientific knowledge is **tentative** (subject to change)		
Scientific knowledge is **empirically based** (based on and/or derived from observations of the natural world)		
Scientific knowledge is **subjective** (involves personal background, biases, and/or is theory-laden)		
The development of scientific knowledge necessarily involves **human inference, imagination, and creativity** (involves the invention of explanations)		
The development of scientific knowledge is **socially and culturally embedded**		
The distinction between **observations** and **inferences**		
The functions of, and relationships between scientific **theories** and **laws**		

10. If nature of science is ***not* taught explicitly** at the school, can you try to identify/explain possible **reasons** for this?
……………………………………………………………………………..……………………………………………………………………..
……………………………………………………………………………..……………………………………………………………………..
……………………………………………………………………………..……………………………………………………………………..

Thank you for your time.

Appendix 3.8
DESCRIPTION OF THE RESULTS CONCERNING THE SCIENCE—AND NOS—TEACHING AT EACH SCHOOL

At each school, individual, semi-structured interviews were conducted with science teachers and the Head of Science (HOD), in order to collect evidence of the school‘s approach and/or policy to teaching science, and specifically, whether or not ideas about NOS were being taught explicitly at the school. If concepts relating to NOS were being taught in science, details of such teaching were sought.

School C

At School C, science in Grades Four to Seven was taught by the school principal who described himself as a subject specialist. According to him, the school‘s approach to teaching science was to make it ―as practical and real as possible”, that is, to help students to ―relate it to the real world”. This was done by, for example, doing various experiments in class, watching a science-related movie (e.g., An Inconvenient Truth), or going on field trips (e.g., visiting the Liesbeeck River when studying ecosystems). From Grade Three onwards, the emphasis in science was on experimentation and investigation, and the development of research skills. When explaining what was taught in his science lessons, the teacher identified content material as the major focus, where subject content matter was extracted from the NCS—but no ideas-about-science were taught.

From this interview with the science teacher (and school principal) at School C, it was concluded that the nature of science was not being taught explicitly at this school.

School J

At School J, the science curriculum was related to, but not solely based upon, the NCS. According to one teacher, the NCS content reflected in local textbooks was ―impoverished” and consequently teachers preferred to teach a different syllabus. That is, at School J, science was taught as part of a ―3way…thematic, integrated approach” that included Design Technology, Natural Science and Social Studies. Social studies included History and Geography. Design Technology was ―an overflow for the science not taught in class because of time restrictions placed on the timetable by Hebrew and Jewish Studies”. School J‘s integrated, multi-teacher science policy necessitated interviews with three staff members at the school, namely, the school principal (who was Head of Science [HOD] and taught Social Studies to the Grade

Sixes, a Grade Six teacher (who taught Social Studies and English), and the Design Technology teacher (who taught the practical science aspects).

An interview with the Head of Science provided a general orientation towards the school‘s approach to teaching science. He explained that science is part of everyday life, and that at elementary school level, general science was taught in order to whet the students‘ appetites before they studied three years of focused science in the Middle School. Upon reaching secondary school (specifically, in Grades 10 to 12) students could then elect to study subjects relating to particular science disciplines (e.g., Physics, Chemistry and Biology). Consequently, in the elementary grades at School J, science content was integrated with other subjects (e.g., A ‗water‘ theme being taught in English was accompanied by experiments conducted during Design Technology lessons). Design Technology was science-based, and the Design Technology teacher taught the ―pure science content" such as electricity (e.g., making a model using electricity), plants (e.g., recording plant growth), and the human body (e.g., students conducted a healthy living survey). The Design Technology teacher described how her lessons typically involved students building a model related to a topic that was being studied in Social Studies. In Social Studies, students learnt about ancient African civilizations (e.g., farming and soil erosion) and the history of medicine (including field trips to the Medical Museum at Grootte Schuur Hospital, and lessons concerning HIV/Aids taught in Life Orientation). In addition to the above, School J held a quarterly Science Week, during which ―the whole school [did] science-based things all week" (e.g., an aquarium workshop, a ―mad scientist" show, and guest speakers such as a local forensic scientist, etc.).

However, when the various teachers at School J were asked about the ideas-about-science that were taught at School J, their responses were: ―Skills are important, for example, how to write up an experiment, and label a sketch" (Head of Science), ―Research and how to take notes are important skills to learn" (Social Studies teacher), and ―All waste can used" (Technology teacher). No reference was made to any NOS-related issues. It was therefore concluded that the nature of science was not being taught explicitly at School J.

School M

At School M, the boys and girls were taught separately, and consequently there were two Heads of Science (HOD). Both teachers were therefore interviewed regarding the school‘s approach to teaching science. The female Head of Science was a Grade Six class teacher but she described herself as a subject specialist. She taught science to both classes of Grade Six girls. Her approach to teaching science was to first establish the students‘ existing background knowledge and then to include information from sources such as the Internet, books, and current media to relate what was being taught in the classroom to the real world. For example, when studying electricity, they talked about Koeberg Power Station and the kinds of work that people do there, as well as discussing the issue of cable theft). Curriculum content was simply what was reflected in the NCS—no ideas-about-science were being taught.

The male Head of Science was a Grade Six class teacher. When describing his approach to teaching science, he said that he taught according to the contents of the NCS. That is, his approach was ―OBE[23] and hands-on". The content being taught was from the NCS, but they also worked from various textbooks and photocopied notes as ―the NCS document isn‘t clear about what to teach and no single textbook coincides with it". When asked what, if any, ideas-about-science were taught, his reply was, ―As it comes up. For example, when teaching electricity, we‘ll discuss the boxes they put it in and compare it to when they send you an account, or we‘ll discuss power failures, energy-saving globes, etc." In other words, his view of teaching ideas-about-science involved relating the content taught in the classroom to the real world in which students live.

In light of the above responses for these two teachers at School M, it was concluded that the nature of science was not being taught explicitly at this school.

Summary regarding the science—and NOS—teaching at Schools C, J, and M

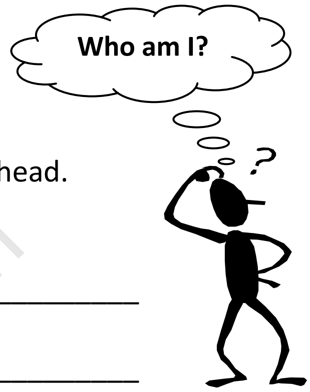
Data obtained during the semi-structured interviews conducted with the various science teachers (and HODs) at the three participating schools, revealed that ideas about NOS were not being taught explicitly at any of these schools. Rather, their science teaching focused on presenting concepts from the National Curriculum Statement (NCS) and/or supplementary syllabi, as well as on the relevance of such concepts for everyday life applications.

[23] Outcomes-Based Education

Appendix 3.9
WHO AM I? QUESTIONNAIRE

Who am I?

PART ONE



Please complete the 15 sentences below. Answer the question:

Write your answers <u>quickly</u> and in the way they come into your head.

1. I am ____
2. I am ____
3. I am ____
4. I am ____
5. I am ____
6. I am ____
7. I am ____
8. I am ____
9. I am ____
10. I am ____
11. I am ____
12. I am ____
13. I am ____
14. I am ____
15. I am ____

PART TWO

In this part of the worksheet I am going to ask you questions about yourself.
I promise not to show your answers to anyone at school.

My name is:	
My Grade 6 class:	Today's date:
School:	

1.a.	How old are you? ……………… years old
1.b.	On what date were you born? Write in the day, month and year if you know them (e.g. 16 December 1994) …………….day ……………………………..month …………….year
2.	Are you a girl or a boy? Circle your answer. Girl / Boy
3.	Where were you born? For example, Cape Town, Johannesburg, etc., or just South Africa if that's all you know. If you don't know, just write "Don't know": ………………………………………………………………………………
4.a.	Where do you live at the moment? ………………………………………………………………………………
4.b.	In total, how many years have you lived where you live now? Write in the total number. If you don't know, just write "Don't know". ……………………………….years
5.a.	Which language do you speak most of the time with your family at home? ………………………………………………………………………………
5.b.	If you speak a second or a third language at home, please write them down: ………………………………………………………………………………

6.a.	What work does your father do? If you don't know, just write "Don't know". If your father does not work, just write "He doesn't work". ……………………………………………………………………………………… ………………………………………………………………………………………
6.b.	What work does your mother do? If you don't know, just write "Don't know". If your mother does not work, just write "She doesn't work". ……………………………………………………………………………………… ………………………………………………………………………………………
7.	How is your life at home when you think in terms of money? This can be your opinion. Please circle your answer. My family is struggling. My family is doing okay. My family lives very comfortably. We are doing very well.
8.a.	What religion do you belong to? ………………………………………………
8.b.	If your parents belong to different religions, please write them down here: Mother's religion ……………………… Father's religion ………………………
8.c.	How strongly would you feel if someone criticized your religion? Circle your answer. Not at all upset Quite upset Very upset
9.	Would you be willing to spend some time with me during school in the next few days to help me with my study? (I would ask you to complete a worksheet, and to do some activities with me during an interview.) Please circle your answer. YES (I am happy to take part.) NO (I don't want to be involved.)

Thank you for your time today. ☺
Robyn (2007)

Appendix 3.10
SUMMARY OF THE FOURTEEN CASES FINALLY SELECTED FOR IN-DEPTH STUDY

Table A3.10-1: Summary of the fourteen students finally selected for in-depth study—representing various religious and gender groups, and diverse views of NOS and of the natural world

Case name	School (Religion)	Gender	Views of NOS (5 aspects)					Views of the natural world (4 descriptions)			
			Tentative	Empirically-based	Theory-laden	Socially- & culturally-embedded	Imagination & Creativity	Epistemological	Ontological	Emotional	Status
Aaeesha	Muslim	Girl	Informed	Informed	Naïve	Informed	Informed	Knowable	Super-naturalistic	Positive	Resource-oriented
Aamir	Muslim	Boy	Naïve	Informed	Naïve	Naïve	Developing	Knowable	Strongly naturalistic	Strongly negative	Strongly Resource-oriented
Brian	Christian	Boy	Naive	Informed	Developing	Developing	Naive	Strongly knowable	Naturalistic	Negative	Strongly conservationist
Dan	Jewish	Boy	Developing	Developing	Developing	Informed	Informed	Knowable	Naturalistic	Positive	Resource-oriented
Dyllan	Christian	Boy	Informed	Naive	Naive	Naive	Informed	Partly knowable & partly unknowable	Super-naturalistic	Negative	Conservationist
Gideon	Jewish	Boy	Informed	Informed	Naïve	Informed	Informed	Strongly unknowable	Naturalistic	Positive	Conservationist
Maya	Jewish	Girl	Informed	Informed	Naïve	Developing	Informed	Knowable	Naturalistic	Positive	Strongly conservationist
Raashid	Muslim	Boy	Developing	Informed	Developing	Developing	Developing	Unknowable	Super-naturalistic	Strongly positive	Resource-oriented
Reza	Muslim	Boy	Naïve	Developing	Naïve	Naïve	Naïve	Strongly unknowable	Strongly super-naturalistic	Neutral	Strongly resource-oriented
Samuel	Jewish	Boy	Informed	Informed	Informed	Informed	Naive	Knowable	Super-naturalistic	Positive	Resource-oriented
Shafia	Muslim	Girl	Informed	Informed	Informed	Informed	Informed	Unknowable	Super-naturalistic	Positive	Strongly conservationist

Table A3.10-1 (cont...)

Case name	School (Religion)	Gender	Views of NOS (5 aspects)					Views of the natural world (4 descriptions)			
			Tentative	Empirically-based	Theory-laden	Socially- & culturally-embedded	Imagination & Creativity	Epistemological	Ontological	Emotional	Status
Victoria	Christian	Girl	Informed	Informed	Informed	Informed	Informed	Knowable	Super-naturalistic	Strongly positive	Strongly resource-oriented
Yamina	Muslim	Girl	Naïve	Developing	Informed	Naive	Informed	Knowable	Strongly super-naturalistic	Strongly positive	Strongly resource-oriented

Appendix 3.11
***VNOS-rs* QUESTIONNAIRE**

What are your thoughts about Science?

Name: ______________________________ Class: ________

School: _________________________ Date: ___ / ___ / 2007

INSTRUCTIONS

- Please answer each of the following questions.
- Some questions have more than one part. **Please make sure you write answers for each part.**
- This is not a test and it will not be graded. **There are no "right" or "wrong" answers.** I am only interested in your thoughts and ideas relating to each question.
- You can draw pictures to help you to explain your ideas if you need to.

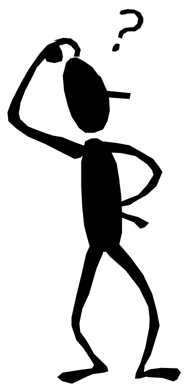
1. a. What kind of work do scientists do?

   b. *Where* do scientists do their work?

   c. *Why* do you think scientists do the work they do?

2. a. Do all scientists work in the *same way*? YES/NO (circle your answer)
   b. Briefly describe how scientific *experiments and investigations* are done.

3. a. Do you think we can *trust* what scientists tell us?
   YES/NO (circle your answer)



   b. Please explain your answer for (3.a.).

4. Scientists are always trying to learn more about our world.
   a. Do you think scientists will *change their minds* about *existing* science facts in the future? YES/NO (circle your answer)

   b. Please describe an example to explain your answer for (4.a).

4. c. Is science only based on *facts*? YES/NO (circle your answer)
   d. Please give an example or explain your answer for (4.c.).

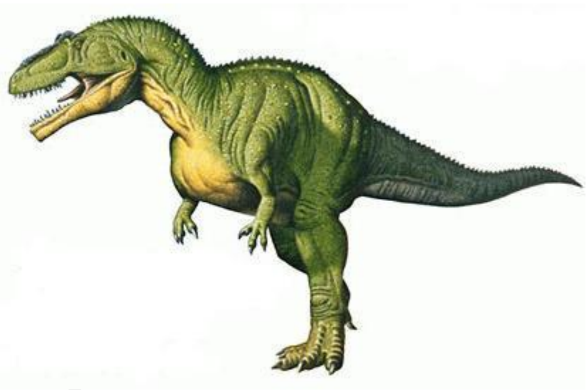
……

……

……

……

5.a. *How do scientists know* what dinosaurs looked like and what they ate?



………………………………………………………………………

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………………………………………………………………………

………………………………………………………………………

………………………………………………………………………

………………………………………………………………………

b. How *certain* are scientists about their knowledge of dinosaurs?

VERY UNSURE / LITTLE BIT UNSURE / CERTAIN / VERY CERTAIN
(circle your answer)

c. A long time ago all of the dinosaurs died. Scientists have different ideas about why and how the dinosaurs died. *Why* do scientists sometimes *disagree* about the answers to questions?

……

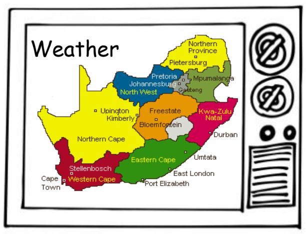
……

……

……

6. Television weather people show pictures of how they think the weather will be for the next day.

   a. *How* do scientists predict what the weather will be like for the next few days?



………………………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

7.a. Scientists try to find answers to their questions by doing investigations and experiments.

b. Do you think scientists use their *imaginations and creativity* when they do their work? YES/NO (circle your answer)

b.i. If you answered NO to (7.a.), please explain *why*.

……
……
……
……

b.ii. If you answered YES to (7.a), describe *when* you think scientists use their imaginations and creativity.

……
……
……

THANK YOU FOR TAKING THE TIME TO THINK ABOUT THESE QUESTIONS FOR ME ☺

Robyn (2007)

Appendix 3.12
ANALYTIC FRAMEWORK FOR ANALYSING THE STUDENTS' NOS VIEWS

Table A3.12-1: Framework for analysing Grade Six students' NOS views, reflecting contents pertaining to the **tentative** aspect of NOS, and detailed for three levels of understanding. Adapted from AAAS (1989, 1993), NRC (1996) and NSTA (n.d.)

Informed view	Developing view	Naïve view
Scientific knowledge is simultaneously reliable and tentative. Scientific knowledge is subject to modification, and the **history of science** reveals both evolutionary and revolutionary changes. When scientists encounter **new experimental evidence** that does not match their existing **explanations and interpretations**, or when a new theory leads to looking at old observations in a new way, old ideas are replaced or supplemented by newer ones. Often the changes in the body of scientific knowledge come about as **small modifications** of principles, theories, and laws in light of new interpretations of existing evidence. However, **large shifts** in the way the scientific community thinks about phenomena also occur. **We are never 100% sure about anything**. The only way something can be proven absolute is if there is no **counterexample**. We can never know that there isn't a counterexample; we can only know that there is a counterexample when we come upon one… Therefore scientific knowledge can change at any time. For example, the theory that the Earth was flat was replaced by evidence it is round. And the model of the atom has developed since the original version people thought of. Also, Pluto has been called a planet for a long time, but it has recently lost its status as a planet and they say we must call it a dwarf planet instead. Although all scientific ideas are tentative and subject to change and improvement in principle, for most major ideas in science, there is much experimental and observational confirmation. Those **ideas are not likely to change greatly in the future**. Some scientific knowledge is very **old and yet is still applicable** today. Scientific knowledge is conditional, never —proven" in an absolute final sense.	Science facts have been proven so they are true. That won't change. However, scientists are still discovering new things so they can add new knowledge to what we already know. For example, they are still finding some of the missing links to do with evolution (i.e., add-on view). The world is changing so scientists know different things. Scientists could get smarter and know more. Scientists make mistakes. Sometimes scientists stop liking one idea and start liking another. In a thousand years' time they will change their minds because they want different things. Improved technology makes things possible.	If you get the **same result over and over and over**, then you become sure that your theory is a proven law, a fact. A science fact is a **fact** and not an opinion. It is true so it **will not change**. For example, the force that keeps us on Earth is called gravity. In science, once you've learnt it, you've learnt it. **Scientists always know the same things**. They don't change what they know. It's written in books. Science is unalterable, fixed truths.

Table A3.12-2: Framework for analysing Grade Six students' NOS views, reflecting contents pertaining to the **empirically-based** aspect of NOS, and detailed for three levels of understanding. Adapted from AAAS (1989, 1993), NRC (1996) and NSTA (n.d.)

Informed view	**Developing view**	**Naïve view**
Science, by definition, is limited to naturalistic methods and explanations and, as such, is precluded from using supernatural elements in the production of scientific knowledge. Scientists formulate and test their explanations of nature using **observation, experiments, and theoretical and mathematical models**. **Accurate record-keeping, openness, and replication** are essential for maintaining an investigator's credibility with other scientists and society. With the dinosaur theory, scientists have collected **evidence from bones and fossils they have discovered**. They did tests on the bones. They have developed **theories** about dinosaurs based on the evidence the have collected. That's how they describe what the dinosaurs looked like and how they lived. They think the earth was quite different when dinosaurs were alive a long time ago. In order to record and predict the weather patterns, scientists use complicated **scientific equipment** so they can take accurate **measurements and readings**. They record all this information and that is what they use to tell us facts about the weather. They can make **calculated predictions based on the data** they collect.	I think scientists have found some bones and fossils from dinosaurs but they can't find much evidence, so they put some theories together and made pictures of the dinosaurs and describe what they think the earth used to look like a long time ago. Scientists don't know everything about the weather and nature, but they can take some measurements with their equipment at the weather stations. The rest they have to kind of work out somehow. That is how they put things together that they tell us about the weather. i.e., science involves more guessing than evidence/facts. Science includes guesses based on the most logical explanation. i.e., acknowledges the basis/use of evidence but unsure *how* scientists investigate (e.g., vague: use machines). Scientists use evidence but I'm not sure I believe what they tell us.	Scientists came up with the idea of dinosaurs because they think there might have been creatures on earth a long time ago that have all died out. Scientists came up with some **theories/ideas** and that is what we believe to be true today. We **can't predict** the weather and we also can't really know everything about nature. But scientists have **some ideas about how things work** and that is what they tell us and it's what we believe. i.e., no evidence.

Table A3.12-3: Framework for analysing Grade Six students‘ NOS views, reflecting contents pertaining to the **theory-laden/subjective** aspect of NOS, and detailed for three levels of understanding. Adapted from AAAS (1989, 1993), NRC (1996) and NSTA (n.d.)

Informed view	**Developing view**	**Naïve view**
Science requires different abilities depending on such factors as the field of study and type of inquiry. Science is very much a **human endeavour**, and the work of science relies on basic human qualities, such as **reasoning, insight, energy, skill, and creativity**—as well as scientific habits of mind, such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas. Not all scientific knowledge has been proven by experiments. Some scientific knowledge/theories arise from **speculation** (e.g. the Big Bang theory), and there are some areas that scientists are still battling out (e.g. nuclear fusion). Scientific ―facts” are subject to a **rigorous verification process**. Having confidence in scientific knowledge is reasonable while realizing that such knowledge may be abandoned or modified in light of new evidence or reconceptualization of prior evidence and knowledge. [Tentative] Science includes theory-laden observations.	Scientists must be fairly certain about dinosaurs because they have published their knowledge in books. But it must be hard to make movies about dinosaurs if we don‘t know have all the facts about them. Some details are still a bit of a mystery, I think. Scientists are still discovering new information. i.e., part evidence. Sometimes the weather forecast is wrong. And sometimes they predict 30% chance of rain. Scientists can‘t ever be 100% sure, because they can‘t predict the future. But their information is correct because it comes from satellite pictures in space, so they can rely on their facts. And as technology improves, so they become more accurate and they know more too. Science includes theories, which are proved correct. Science includes myths…they are partly true/scientists test them/confirm if they are true or not. I disbelieve certain ―theories”/”stories”/versions of science.	*CERTAIN:* Scientists are very sure about the dinosaurs because they have collected **facts and evidence**, and their knowledge has been **published in books**. It‘s what we are taught at school. The scientists that lived a long time ago must have seen them (dinosaurs) first and then told other scientists. There are people who are **experts** in studying the weather. They wouldn‘t stand up in front of the television of they weren‘t sure about what they were saying. Modern technology helps scientists a lot, for example these days they can warn people when there‘s going to be a hurricane or a big storm because they can see it coming with their **specialised equipment**. Science involves neutral/objective observations. Scientists disagree because they make mistakes. *or* *UNCERTAIN:* Scientists can‘t be very sure about dinosaurs because dinosaurs lived millions of years ago before humans were around so **they can’t really know what it was like** then. Also, scientists keep digging up new fossils so then they **change their minds** about how a dinosaur‘s neck looked or what it ate, etc. The weather people aren‘t sure about everything like tsunamis, and they don‘t always know when a really bad storm is going to hit the land. They have some ideas about what causes floods, etc. but they **don’t have all the answers**; i.e., no facts are used (nor is there mention of the development of theories).

Table A3.12-4: Framework for analysing Grade Six students' NOS views, reflecting contents pertaining to the **socially- and culturally-embedded** aspect of NOS, and detailed for three levels of understanding. Adapted from AAAS (1989, 1993), NRC (1996) and NSTA (n.d.)

Informed view	**Developing view**	**Naïve view**
In areas where active research is being pursued and in which there is not a great deal of experimental or observational evidence and understanding, it is normal for scientists to differ with one another about the interpretation of the evidence or theory being considered. The scientific **questions** asked, the **observations** made, and the **conclusions** in science are to some extent influenced by the **existing state of scientific knowledge,** the **social and cultural context** of the researcher and the **observer's experiences and expectations**. Different conclusions arise because different people are involved. Just because scientists have access to and use the same set of data to derive their conclusions doesn't mean that they are going to come up with the *same* conclusions. Their conclusions are surely consistent with the evidence but also somewhat based on the type of **training and education** they have received, their **prior knowledge, personal belief system, own imaginations, expectations**, etc. Scientists are **human**. They learn and think differently, just like all people do. They interpret the same data sets differently because of the way they learn and think. Ideally, scientists acknowledge such conflict and work towards finding evidence that will **resolve** their disagreement. Scientific knowledge is constructed through social negotiations (e.g., scientists vote to resolve disagreements).	Scientists might look at information from different perspectives and have their own opinions about things. Maybe there's just not enough evidence about dinosaurs for scientists to build their theories on this topic, so they come up with different ideas to explain how they think things were on earth millions of years ago. But major disagreements can't be possible because there must be a real explanation for things, so maybe some of the scientists are wrong. Perhaps some of the scientists are less skilled or don't have as much experience as others so they come up with different explanations. Different conclusions arise because different evidence is found.	Science is about **facts** and about things that are or are not true. **There can't be conflicting reasons or explanations.** For example, the sun rises and sets the same in every country in the world. Different conclusions are not possible. Some of the scientists must be **wrong** or maybe there's **not enough data** available to decide who is right. Or they must be looking at **different parts of the data**. If they looked at the exact same data they wouldn't disagree. (i.e., scientists make mistakes). Scientists are very **objective** because they have a **set way of doing things** and they have to be **specific and accurat**e when they do their experiments. There is **no room for personal opinions and viewpoints** in science. So one of the scientists must be wrong or maybe his results/evidence wasn't accurate.

Table A3.12-5: Framework for analysing Grade Six students‘ NOS views, reflecting contents pertaining to the **imaginative/creative** aspect of NOS, and detailed for three levels of understanding. Adapted from AAAS (1989, 1993), NRC (1996) and NSTA (n.d.)

Informed view	Developing view	Naïve view
Science is very much a **human endeavour**, and the work of science relies on basic human qualities, such as reasoning, insight, energy, skill, and creativity—as well as scientific habits of mind, such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas. **Creativity** is a vital, yet personal, ingredient in the production of scientific knowledge. For example, scientists must have used their **imaginations** to explain how the dinosaurs died. Scientists‘ conclusions are surely consistent with the evidence but sometimes they need to apply their imaginations and creativity when they make **connections** between different pieces of information and **explain how things fit together**. Scientists also need to be creative in tackling problems or questions from **different angles** and considering different **alternatives**. Scientists differ greatly in what phenomena they study and how they go about their work. There is **no fixed set of steps** that all scientists follow and no single universal step-by-step scientific method that captures the complexity of doing science. Scientists‘ imaginative acts are part of science.	Science is mostly about facts and what‘s true about how things work in nature. It can‘t just be based on people‘s imaginations and creativity. But every now and then scientists might have a ―bright idea” because of something they think of, and that comes from their own minds/imaginations/creative thinking. Scientists mostly have a set way of doing experiments and investigations. But sometimes they might do something a little differently to see what happens to their results. Sometimes scientists might not be smart enough so then they might imagine how something works. Science involves the use of imagination, plus facts also.	Science is different to art. An artist uses his imagination and creativity in designing and making things. Science is different. It is about hard **facts**. Science is either true or it‘s not true. There‘s **no room for creativity or imagination in science**. Scientists have to know stuff, not imagine stuff that‘s not real. They want to really figure things out and not tell lies. They want to tell the **truth**. Science is **objective** and the **data** is either there or it is not. If scientists use imagination and creativity in their work they will not come to **real answers**. Scientists are very objective because they have a **set of procedures** that they use to solve their problems. Artists are more subjective, putting themselves into their work. You can **repeat a science experiment** to show the same thing, and your conclusion is based on **logic** from your actual results. Scientists are **smart** so they don‘t have to imagine.

Appendix 3.13

ANALYSIS OF DYLLAN'S VIEWS OF NOS (IN TERMS OF LEVELS OF UNDERSTANDING), ORGANISED PER NOS ASPECT

Table A3.13-1: Analysis of Dyllan's views regarding the **tentative** nature of science

Level of understanding	**Informed view**	**Developing view**
Extracts from written *VNOS-rs* responses and the immediate review thereof, as well as statements made during the follow-up interview	Scientists say that there is an Earth like ours somewhere else. They say that the fastest rocket will take 300 000 years to get there. Maybe they're wrong…With new technology, Maybe our fastest rocket will be faster so it will take only 200 000 years to get to the other Earth. Or maybe that Earth is closer than what they say it is. I've got a example for scientists changing their facts…Like, who told my dad that there was just blackness in space? Probably his last science teacher. And now a new science teacher is saying there's stars and stuff like that. Or they're saying that…back then, they were probably saying that it's one sun and nine planets and now they're telling us that there's plenty. That's an example of facts changing.	Say the Voyager 1 passed Pluto and now it's shut down, it's not getting any sunlight and now it's travelling for a long time and there's a planet that looks similar to Pluto or maybe has the same structure as Pluto and now they get sunlight again and they say, ―A, it it's just past Pluto, and it receives light from somewhere else." But it's not Pluto. It's, like, a different planet. Something like that. …If scientists say…there's a hundred billion galaxies, then it will be on the news, or it would be on the Internet as a interesting fact. But I haven't experienced something when they say scientists said this and then next time they say scientists are wrong, they made a mistake or something like that. I haven't experienced that yet, m'am[1]…I think it could happen. But I can't think of an example…[it hasn't happened yet] to me, but maybe it has happened to people that lived before me.

Overall level of understanding: Informed

Table A3.13-2: Analysis of Dyllan‘s views regarding the role of **empirical evidence** in science

Level of understanding	Informed view	Naïve view
Extracts from written *VNOS-rs* responses and the immediate review thereof, as well as statements made during the follow-up interview	Scientists do their work in a lab with chemicals that help them know more about what they are dealing with. People sometimes think they found an alien in their house then scientists do tests on it to tell that person if it is an alien or not. They use chemicals in their lab, and then maybe some other scientists work with technology, like, make computers and stuff like that. [Re: weather predictions] They take a picture of space and that‘s how they know or the clouds are grey also another way to tell. They sent pictures, they sent, like, a Voyager out to space and, like, that took pictures of space, so that would give them idea of what it was like.	[Re: Is science only based on facts?] I don‘t know...It is based on what they tell us. [Re: How do scientists know about dinosaurs?] I don‘t know how they knew…Nobody really lived back then. [Re: Where do scientists get their information from?] It‘s pretty strange…because, like… Mr. [B][24] had this book. And it showed us of, a picture of the sun, up close, but wouldn‘t that Voyager 1 burn if it was up close, you know? Or…they took a picture of the Milky Way galaxy how it looks in space. But the Voyager 1 only passed Pluto now! And that‘s the first one that we sent out, so…maybe they‘re tricking us. …Scientists haven‘t been up close to Saturn and, you know the Voyager 2 or 1, I think it was the first one they sent out, that‘s only passing Pluto now…Maybe it‘s a long time past Pluto. That‘s another thing, M‘am…That‘s what Mr. [B] says, M‘am. Voyager 1 that was sent out so they can experience our solar system, Mr. [B] says it‘s only gone passed Pluto now…And that it‘s shut down because it works off solar power and now it‘s not getting any sun because it‘s past Pluto. So, maybe it‘s not past Pluto. I don‘t know, M‘am. It‘s strange. Or maybe, as they passed Pluto another sun came so it was still on…it‘s quite confusing! Archaeologists found bones, fossils, fossils of the dinosaurs, but obviously the skin has been eaten up by…and then, all they find is the bone, and they brush it and that, and all they see is the bone. But what if they are fooling us by just putting on skins but with the shape of the dinosaur‘s body and then they find another one and just put, just make his skin colour green. But if you go back in time it‘s red…? I‘m not too sure [how scientists go about their work] because I‘ve seen a lot of movies and they say, ―We must go our lab," and then they have chemicals and technology and stuff, and then I think they just do that. But I‘m not too sure if they also…‗cos I know space is Nature because it always was there, but they don‘t really study, they don‘t work with that, because they can‘t touch the planets, do you know what I mean?

Overall level of understanding: Naive

[24] Dyllan‘s current science teacher at school

Table A3.13-3: Analysis of Dyllan‘s views regarding the **theory-laden and subjective** nature of science

Level of understanding	Informed view	Naïve view
Extracts from written *VNOS-rs* responses and the immediate review thereof, as well as statements made during the follow-up interview	I have heard people say that there was no food so the dinosaurs died. And I heard a volcano killed the dinosaurs. But no-one was alive then so it was difficult to give a right answer. It is very difficult to say how scientists know how dinosaurs look like because they weren‘t there.	Scientists say that the space comes to an end. I really don‘t believe. I think it goes on forever. [Re: Is what science tells you the absolute truth?] Mmm, no. M‘am, because, why I say no, m‘am, is because Mr. [B] says if I go out to space…swim in space…it‘s a pool. Then, Mr. [B] said I will see stars and I will see comets and I will see…maybe a dwarf sun or something like that, m‘am. And then my Dad says different. He says if I go out to space I will just see blackness unless there is a planet in front of me. So that‘s why I say, m‘am, I don‘t…you see, it‘s confusing like that, m‘am…I would say that I believe Mr. [B], because if you look up you will see millions of stars so obviously if you go up to the stars it will be all around us…I believe Mr. [B], but, I don‘t believe that there‘s nothing there but planets. I don‘t believe that, m‘am. …Scientists haven‘t been up close to Saturn and…you know the Voyager 2 or 1, I think it was the first one they sent out, that‘s only passing Pluto now…Maybe it‘s a long time past Pluto. That‘s another thing…That‘s what Mr. [B] says...Voyager 1 that was sent out so they can experience our solar system, Mr. [B]says it‘s only gone passed Pluto now…And that it‘s shut down because it works off solar power and now it‘s not getting any sun because it‘s past Pluto. So, maybe, maybe it‘s not past Pluto. I don‘t know…It‘s strange. Or maybe…as they passed Pluto another sun came so it was still on. It‘s quite confusing!…Say the Voyager 1 passed Pluto and now it‘s shut down, its not getting any sunlight and now it‘s travelling for a long time and there‘s a planet that looks similar to Pluto or maybe has the same structure as Pluto and now they get sunlight again and they say, ―Ah it‘s just past Pluto, and it receives light from somewhere else.” But it‘s not Pluto. It‘s like a different planet.

Overall level of understanding: Naive

Table A3.13-4: Analysis of Dyllan‘s views regarding the **socially- and culturally-embedded** nature of science

Level of understanding	**Naïve view**
Extracts from written *VNOS-rs* responses and the immediate review thereof, as well as statements made during the follow-up interview	[Re: Why do scientists sometimes disagree?] They don‘t have enough facts. [Re: If scientists disagree, it‘s] probably [because of] new technology. [It‘s not really okay that scientists disagree about things] because…for instance, [if] I have a test. And my dad and I study for the test and I read out something that‘s given in our notes that we‘re gonna be tested on that says, [for example] that the Milky Way has twenty solar systems, and now my dad disagrees with that and he says it only has one. And then I write on my test ―one" and then I get marked wrong. And then that might just give me one mark off full marks, or I might fail because of that.

Overall level of understanding: Naive

Table A3.13-5: Analysis of Dyllan‘s views regarding the role of **imagination and creativity** in science

Level of understanding	**Informed view**
Extracts from written *VNOS-rs* responses and the immediate review thereof, as well as statements made during the follow-up interview	Archaeologists found bones, fossils, fossils of the dinosaurs, but obviously the skin has been eaten up by…and then, all they find is the bone, and they brush it and that, and all they see is the bone. But what if they are fooling us by just putting on skins but with the shape of the dinosaur‘s body and then they find another one and just put, just make his skin colour green. But if you go back in time it‘s red…? Maybe scientists…like I said with the things called the Pterodactyl…it‘s a flying bird, and they said he eats a lot of plants. Maybe that‘s why they just make him a yellow colour. But what if he ate meat?! …Because in movies they mostly make, like, dinosaurs, like, eating machines…you know even the dinosaurs that eat plants that I‘ve heard back then,…like, when I was in…Grade Two…they said that…most dinosaurs eat plants and some eat meat, and some eat both. What if they all ate meat…? It‘s difficult to just make up a fact. Maybe they use their imagination.

Overall level of understanding: Informed

Table A3.13-6: Analysis of Dyllan‘s views regarding the **nature of scientists’ work**

Extracts from written *VNOS-rs* responses and the immediate review thereof, as well as statements made during the follow-up interview	Scientists do their work in a lab with chemicals that help them know more about what they are dealing with. [Re: How do scientists do their work?] I‘m not too sure…They use chemicals and they‘re in their labs, but I‘m not sure exactly how they do their work…and then maybe other scientists work with technology, make computers and stuff like that. M‘am, does scientists only study things like technology, or do they study, like, or do they work with Nature? I‘m not too sure, m‘am, because I‘ve seen a lot of movies and they say, ―We must go our lab,” and then they have chemicals and technology and stuff, and then I think they just do that. But I‘m not too sure if they also…‗cos I know, like, space is Nature because it always was there, but they don‘t really study- they don‘t work with that, m‘am, because they can‘t touch the planets, do you know what I mean, m‘am?...[So [I] think it‘s mostly in the lab with the chemicals and things that they do.].

Table A3.13-7: Analysis of Dyllan‘s views regarding the **role/purpose of science**

Extracts from written *VNOS-rs* responses and the immediate review thereof, as well as statements made during the follow-up interview	Scientists are people who find out things about space and old people that used to live on Earth. Scientists answer people‘s questions (i.e., people‘s questions about living things). Mr. [B]s science book says that the universe comes to an end but I‘m not sure it‘s possible. I‘m not too sure [how scientists go about their work] because I‘ve seen a lot of movies and they say, ―We must go our lab,” and then they have chemicals and technology and stuff, and then I think they just do that. But I‘m not too sure if they also, ‗cos I know like space is Nature because it always was there, but they don‘t really study, they don‘t work with that, because they can‘t touch the planets, do you know what I mean? They use chemicals in their lab, and then maybe some other scientists work with technology, like, make computers and stuff like that. People sometimes think they found an alien in their house then scientists do tests on it to tell that person if it is an alien or not.[25]

[25] [Re: The existence of aliens] I think aliens do exist…There‘s millions, millions of planets. Because I looked up on the Internet about galaxies about the universe and they said there are more than a hundred billion galaxies…and that…each galaxy holds at least fifteen planets, and that‘s a *lot* of planets. So there must be….more people in the…universe. And…ja, and then aliens, probably, like animals, far out in the universe.

Table A3.13-8: **Explicit conflict** articulated by Dyllan (Parents vs. Teacher/science)

Extracts from written *VNOS-rs* responses and the immediate review thereof, as well as statements made during the follow-up interview	Did I tell you this example before, m'am? That my Dad said there is only one sun and nine planets, but Mr. [Bester] said one sun and nine planets in our galaxy, but Mr. [B] said there's one sun and nine planets in our solar system, but there's like ten more in our galaxy. [Re: Is what science tells you the absolute truth?] Mmm, no. M'am, because, why I say no, m'am, is because Mr. [B] says if I go out to space…swim in space…it's a pool. Then, Mr. [B] said I will see stars and I will see comets and I will see…maybe a dwarf sun or something like that, m'am. And then my Dad says different. He says if I go out to space I will just see blackness unless there is a planet in front of me. So that's why I say, m'am, I don't…you see, it's confusing like that, m'am…I would say that I believe Mr. [B], because if you look up you will see millions of stars so obviously if you go up to the stars it will be all around us…I believe Mr. [B], but, I don't believe that there's nothing there but planets. I don't believe that, m'am.

Appendix 3.14
BASIC WORLDVIEW INTERVIEW PROTOCOLS

The interview protocols employed in the present study (i.e., Table A3.14-1, Table A3.14-2 and Table A3.14-3) were adapted from the basic interview protocols described by Cobern (2000b:159-162).

The worldview interview began with a cheerful greeting and a few introductory comments. The student was made to feel comfortable and asked to present her/his signed consent form to the researcher. The researcher confirmed the students‘ prior permission to record the interview and briefly explained how the recording device worked. In order to familiarize themselves with the recording device, the student was then asked to record her/himself by introducing her/himself into the recorder.

The interview then proceeded through Tasks One (Table A3.14-1), Task Two (Table A3.14-2) and Task Three (Table A3.14-3), as detailed below.

Table A3.14-1: Worldview interview protocol for **Task One** (i.e., Images of Nature)

INTERVIEWER SAYS	INTERVIEWER DOES
I would like to talk to you about Nature, or the natural world, or the natural environment. Do these words mean the same thing to you?	The recording device continues recording after the student has introduced her/himself.
If not, please tell me what you understand by the meaning of each one. Which one will be the easiest for us to use today?	If a distinction is being made, combine definitions or otherwise resolve.
Now to begin with I would like you to please close your eyes.	Wait for the student‘s eyes to be closed.
Imagine you are somewhere in Nature. It could be anywhere. Think about what it is like there, for example, what you see around you. Please describe this place in Nature to me.	
Have you been to a place like this?	
If so, please tell me more about this experience of Nature.	
Okay, now imagine you have left that place and suddenly arrive in a different place in Nature. Think about where you might be now, in this different place.	
What do you see around you now? Please describe to me what it is like in this new place in Nature.	
Have you been to a place like this before?	
If so, please tell me more about this experience of Nature.	
You can open your eyes now.	Wait for the student‘s eyes to be opened.

Table A3.14-1 (cont…)

INTERVIEWER SAYS	INTERVIEWER DOES
I have some pictures here that I would like to show you. Please look at them carefully for me. Is there anything there that you think is part of Nature? If so, which parts are Nature, do you think? Why do you say it is Nature? *OR* What makes it part of Nature? Is there anything *else* here that is part of Nature? Please tell me a bit about that as well? Is there anything here that is *not* part of Nature? What makes it *not* part of Nature? Is there anything *else* here that is *not* part of Nature? Please tell me a bit about that as well? Is there anything in Nature or about Nature that you would like to find out more about? Please tell me what you would like to know more about (i.e., with regards to Nature). Is it possible to know these things about Nature? How do you think we can find out about things in Nature? Who else studies Nature and finds out things about Nature? What do they do? That is, how do they find out what they tell us about Nature? Do you think we can trust what they tell us about Nature? Why/Why not? Why do those people study Nature? Is there anything else you'd like to say about any of these pictures, or about Nature? I am going to put this over here so you can still look at it, and use it if you need to, later on.	Place the Nature collage on the table and let the student look at it. Pause while the student examines the pictures.

Table A3.14-2: Worldview interview protocol for **Task Two** (i.e., Word sort and sub-group)

INTERVIEWER SAYS	INTERVIEWER DOES
We are going to go through a series of cards. I am going to ask you to think about the words and then I will ask you to comment about them.	Put up signs: NATURE IS... and NATURE IS NOT...
Remember, what we are focusing on is what Nature is. I want you to divide these cards into two groups. One group of words are the ones that you would use when talking about Nature (those go under the heading *Nature is*) and one group that you would not use (those go under the heading *Nature is not*).	

Table A3.14-2 (cont…)

INTERVIEWER SAYS	**INTERVIEWER DOES**
While you put each word in a group, I want you to please give me an example or try to explain your thoughts and ideas to me. Remember it is not a test so there is no right or wrong answer. If there are any words that you don‘t understand, please ask so I can help you.	Begin with a word, chosen randomly. Repeat for each of the words. A middle/undecided group may be formed if required.
Why are you saying ―Nature is _________”? What do you mean when you say ―Nature is ___________ ―? In what sense would you say ―Nature is ___________”? What examples can you give me?	During the sorting process, ask clarification questions where necessary. Avoid ―Okay.” Ask non-directed questions that invite the student to talk about why the terms were picked and what they mean. Ask for examples. Ask follow-up questions were appropriate.
Now, let us talk about these words. Some of them might be about the same thing. I want you to have a look at them and put them in groups if there are some that go together. Maybe they have a similar meaning or they talk about the same thing about Nature. Some might not belong in a group so they can stay on their own, and that is okay.	Take words in the *Nature is* group and spread them out in front of the student.
Great. Now if I asked you to explain to someone what Nature is, which group of words would you choose to tell them about first?	Wait for the student to group the words.
Why did you choose this group first? Well done. Now, which group would you choose next if I asked you to describe to someone what the natural world is like?	Repeat chosen words for the recorder. Repeat for each sub-group.
Can you help me understand this? Why is it... on the one hand (name the first or previous groups) and on the other it its (name the present group)?	Go back through the question series as above. Look for conflicting words. Ask how the first group relates to the second group or if they do. Paste the sub-groups onto blank paper, numbered and labeled. Put the sheet to one side but keep it visible.
Okay, now we‘re going to do the same thing with the *Nature is not* words. If you were to describe to someone what Nature is not, which group of words would you tell them about first?	Repeat the process using the words in the *Nature is not* pile (and the *middle/undecided* pile, if there is one).
Let us quickly paste these words onto paper so that I do not lose any of them.	Paste the words in their sub-groups on blank paper, numbered and labeled.

Table A3.14-3: Worldview interview protocol for **Task Three** (i.e., Statement sort & Dyad comparison/rank)

INTERVIEWER SAYS	**INTERVIEWER DOES**
For our last activity I am going to show you some sentences. Some of them you might think, ―Yes, Nature is like that” and you agree with what the sentence says about Nature. In which case, please put it under the heading *Yes/Agree*. Some of the sentences you might disagree with what they say—you might think Nature is not like that—those sentences will go under the heading *No/Disagree*. Again, I would like you to try to give me an example or explain your thinking to me as you group the sentences. And if there is anything you do not understand or something you‘re maybe not sure about, just ask.	Put up signs: YES/AGREE and NO/DISAGREE
	Begin with a sentence, chosen randomly. Read it aloud to the student, and allow her/him to group each word under one of the headings. A *middle/undecided* group may be formed if required. Repeat for each of the sentences.
Why are you saying ―Nature is _________”? What do you mean when you say ―Nature is ___________”? In what sense would you say ―Nature is ___________”? What examples can you give me?	During the sorting process, ask clarification questions where necessary. Avoid ―Okay.” Ask non-directed questions that invite the student to talk about why the terms were picked and what they mean. Ask for examples. Ask follow-up questions were appropriate.
We will start with this group of *Yes/Agree* sentences. I am going to show them to you two at a time. I want you to please choose one to keep and one to be replaced. Then I will pick another sentence and you can again choose which one to keep and which one to put aside. We will keep the ones you put aside beneath each other in a column like this under their heading (i.e., *Yes/Agree*).	Take the words in the *Yes/Agree* group and mix them together. Randomly select two sentences and hand them to the student.
Can you help me understand this? Why is it ...on the one hand (name the statement/s) and…but here you said you feel it is… (name the previous word/s)?	Go back through the words that were sorted in Task Two and compare them to the statements that were sorted in Task Three. Look for conflicting words/statements. Ask how the statements relate to the words, or if they do. Show the first two statements to the student. S/he selects one to keep and puts the other one aside. Show her/him a third statement. S/he compares it to the one s/he chose to keep, and puts the other statement aside, beneath the first statement s/he put aside.
Let us place this sentence you have kept, at the top of this column. Then below that we will put these ones you also felt were important about Nature, which we marked with a star. Then after those we will keep all the other *Yes/Agree* statements.	This continues until all the *Yes/Agree* statements have been compared. The one s/he chose to keep finally is labeled #1 and placed at the top of the *Yes/Agree* column. Statements that were held for three or more turns are marked as important with an asterisk. All the statements with asterisks are placed beneath the #1 statement, followed by all the remaining statements.

Table A3.14-3 (cont…)

INTERVIEWER SAYS	INTERVIEWER DOES
Let us quickly paste these statements onto paper so that I don't lose any of them.	Paste the statements in order, onto blank paper, numbered and labeled.
	Repeat the ranking procedure with the *No/Disagree* statements (and also with the *middle/undecided* group, if there is one).
So if we look at these statements now, would you say that the statement that you feel most strongly describes Nature is this one (*Yes/Agree* #1)? And the one you disagree with the strongest is this one, that Nature is not (*No/Disagree* #1)?	Allow the student time to briefly reflect on the outcome of this ranking activity.
Before we end off, is there anything else you would like to say? Do you have any questions you would like to ask? Thank you so much for your help today and for chatting to me. I really enjoyed that.	Conclude by asking if there is anything the student wishes to add, or if there are any questions s/he still has.

Appendix 3.15
DETAILS OF THE FORMAT OF THE INTERVIEW TRANSCRIPTS, AND THE NOTATION SYSTEM USED IN TRANSCRIBING THE INTERVIEWS

Transcript formatting

Each worldview interview transcript comprised six columns (i.e., *REF*, *ID*, *INTERVIEW TEXT*, *CODES*, *EXAMPLES*, and *CLASSIFICATION*), as presented in Table A3.15-1.

Table A3.15-1: Details of the columns used in the transcripts of the worldview interviews.

Column heading	Contents of each column
REF	Line reference number for each of the speaking turns
ID	Identity of the speaker: R=Researcher; S=Student.
INTERVIEW TEXT	Verbatim transcript of the interview dialogue
CODES	Analytic codes assigned to segments of the data: • Multiple speaker turns were sometimes combined to form a chunk of meaning, which was then assigned a single code; • In some instances, more than one code was assigned to a data segment. (e.g., Appendix 3.16 [page 309]: Line 56: Frightening)
EXAMPLES	Specific examples cited by the student in explaining his views. (e.g., Appendix 3.16 [page 309]: Line 57: Tornado, hurricane)
CLASSIFICATION	Classification of codes according to the four bipolar descriptor pairs, namely, Knowable/Unknowable, Super-naturalistic/Naturalistic, Positive/Neutral/ Negative, Resource-oriented/Conservationist). (e.g., Appendix 3.16 [page 309]: Line 57: Negative)

The transcripts of the follow-up interview[26] comprised five columns (i.e., *REF*, *ID*, *INTERVIEW TEXT*, *KEY CONTENT*, *LEVEL*). The first three headings were the same as those presented in Table WT-1. Details regarding the fourth and fifth column headings are provided in Table A3.15-2.

Table A3.15-2: Details of the fourth and fifth column headings of the transcripts of follow-up interviews

Column heading	Contents of each column
KEY CONTENT	Codes assigned to data segments (e.g., Know) and/or NOS aspects (e.g., Tentative). Additional memos were also recorded in this column whilst transcribing and coding the data from the follow-up interview.
LEVEL	Classification of responses according to bipolar descriptor pairs (e.g., Knowable) and/or levels of NOS understanding (e.g., Informed).

[26] Follow-up interviews included questions relating both to the students views of the natural world and their views of NOS.

Transcription notation

The general notation system used for all interview transcripts is presented in Table A3.15-3.

Table A3.15-3: Explanation of the notation system used in the interview transcripts

Notation	Explanation of meaning of notation used
[…] (i.e., ellipsis in square brackets)	Indicates where a portion of dialogue was omitted. These typically included asides or fillers that did not add significant meaning to the contents of the interview. Such utterances were removed in order to de-clutter the transcript.
(…) (i.e., ellipsis in round brackets)	Indicates where there was a pause in conversation.
(text) (i.e., in round brackets)	Includes descriptions of gestures or actions that were not reflected in the audio recording, but which were needed to explain certain portions of the dialogue. Also indicates where the one person interjected during the other person‘s speaking turn.
Text (i.e., in italics)	Indicates where a particular word received emphasis by the speaker.
Text (i.e., in bold)	Indicates words and/or statements reflected on the various prompt cards used in Tasks Two and Three, respectively. (e.g., Appendix 3.16 [page 309]: Line 54: **Can be used**)
[unclear]	Indicates where a portion of the dialogue was unclear in the recording.
―text” (i.e., in quotation marks)	Indicates the original question or original written responses being read from a document (e.g., *VNOS-rs* questionnaire or worldview narrative) (e.g., see transcript for follow-up interview).

Appendix 3.16
TRANSCRIPT OF DYLLAN'S WORLDVIEW INTERVIEW

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
1.	S	[The student introduces himself to familiarise himself with the recording equipment.]			
2.	R	We‘re going to talk about ‗Nature‘ (Nature, okay.) or the ‗natural world‘, or the ‗natural environment.‘ Do all those words mean the same thing?			
3.	S	Yeah.			
4.	R	So if I use the word Nature, is that okay?			
5.	S	Yes, that‘s fine.			
6.	R	Okay, good. So now close your eyes (The student closes his eyes.) and I want you to imagine that you are somewhere in Nature. And imagine what it‘s like around you and what the things are around you, and then describe to me, where you are or what it‘s like, or what‘s around you.			
7.	S	I‘m in the jungle and I see lots of palm trees and there‘s lots of sand around, and lots of plants. And I see a path. And there‘s animals, monkeys, and pandas.		Jungle, palm trees, sand, plants, animals, monkeys, pandas	
8.	R	Ah, wow! Have you been to a place like this?			
9.	S	No.			
10.	R	Interesting! And if you were to imagine another place in Nature, so we‘ve got a jungle with sand and lots of plants and monkeys and things…if you were to imagine another kind of place in Nature, what would it be like?			
11.	S	On the beach.		Beach	
12.	R	Ah! And what‘s it like there?			
13.	S	It‘s just me alone, and I can see water, sand, and lots of wood.		Water, sand, wood	
14.	R	Wood? That‘s interesting.			
15.	S	Lots of wood.			
16.	R	Where‘s the wood from?			
17.	S	Maybe cut down trees, and it‘s next to me.		Trees	
18.	R	Okay. And other things that you see there, besides the water and the sand and the wood?			
19.	S	No.			
20.	R	Now, is *that* a place you‘ve been to before?			
21.	S	No.			
22.	R	Also in your imagination.			
23.	S	Yes, m‘am.			

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
24.	R	Excellent! Okay, good. So now we‘ve got jungle ideas and beach ideas, okay. I‘ve got some pictures here that I want to show you. And I want you to have a look and tell me are there any here that you think are pictures of Nature or parts of Nature?			
25.	S	Must I point them out?			
26.	R	Ja! Or talk about them if there are things that are…			
27.	S	What‘s that, m‘am?			
28.	R	That looks like a…a hurricane or a tornado or something…. You know, kind of, looking at the earth from above.		Hurricane, tornado	
29.	S	All these pictures are a part of Nature, m‘am.			
30.	R	Okay.			
31.	S	Except for this. (The student points to the picture of the astronaut.)		Astronaut	
32.	R	The astronaut. Why is he not a part of Nature?			
33.	S	He‘s got lots of machines on his back (Mmm.) and that‘s not part of Nature (Mmm.) It‘s man-made stuff.	Not man-made	machines	Definition of Nature
34.	R	So what makes Nature Nature?			
35.	S	I think plants and stuff that man didn‘t make (okay.) like that (Bees.) and that (Fossil.) and that (Nest)…(okay). Except that car (okay.) and the water and the dogs and puppies and volcanoes, and the banana, and fires… and this (i.e., fossil), m‘am, nobody created that.	Not man-made	Plants, bees, fossil, nest, car, water, dogs, puppies, volcanoes, banana, fires	Definition of Nature
36.	R	That fossil?			
37.	S	Yes, m‘am.			
38.	R	Good. And are there things that you would want to find out more about, about Nature, if I said to you, right, we can study something in Nature? Is there anything that you are interested in or have questions about, or want to know about?			
39.	S	How do plants grow? (Aha.) What‘s in the plants that makes them shoot out? That‘s what I would like to know.	Don‘t know	Plants	Unknowable
40.	R	Good question! How do you suppose…how do we find out things about Nature?			
41.	S	Internet, books, and we can experience it ourselves, by going to the jungle or somewhere.	Know/Learn; Observe	Internet, books, personal experience, jungle	Knowable
42.	R	Ja. And tell me, when…now you say you can experience itself and then you can now things, and the information that‘s on the Internet and in books and what have you, how did that, you know, how did we get that information? Where did those facts come from?			
43.	S	Oh, maybe somebody went to the jungles or experienced a volcano erupting or something like that themself. Maybe they‘re archeologists that (unclear) the fossils and everything.	Know/Learn; Observe	personal experience, jungle, volcano, archeologist	Knowable

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
44.	R	Okay, good, brilliant.			
45.	S	And they are farmers, maybe. They collect honey then they see how the bees make the honey. Or they are farmers with the cows, and see how they make the milk and everything.	Know/Learn; Observe	Farmers, honey/bees, milk/cows	Knowable
46.	R	Okay, so they are experiencing Nature or they are working with it or they‘re doing things with it and so they know things about it.	Know/Learn; Observe		Knowable
47.	S	Yes, m‘am.			
48.	R	Okay, good. And are there any other pictures here that you want to say anything about, or…			
49.	S	Um, no.			
50.	R	Okay, so what we can do is keep this to the side so then you can look at it if you need to. (The interviewer moves the collage to one side of the table.) Um, okay, the first thing I want us to do is I‘m going to show you some words. Okay, and some of them you will be what you think Nature is (The interviewer places the caption ―Nature is" on the table in front of the student.) and you can put them under that heading, and some of them will be what you think Nature is not (The interviewer places the caption ―Nature is not" on the table in front of the student.) and then you can put them under that heading. (Okay.) Okay, and then each time you decide which heading it goes under, if you can, um, explain to me why you think it goes there, or give me an example, maybe. (Okay.) And these are just in random order, so it‘s a whole mixture of things…Do you think Nature is **orderly**?			
51.	S	Yes, m‘am.	Orderly		Knowable
52.	R	Hmm, tell me about that.			
53.	S	Um, okay so the cows, they eat lots of grass, then their tummies get big then they give us milk (Okay.). Then we drink the milk to stay healthy so we can still feed them, like a cycle. It is orderly.	Cycle, Orderly	Cows, grass, milk	Knowable
54.	R	Nice example. Do you think Nature **can be used**?			
55.	S	Yes. (Mmm.) We use the bees‘ honey, and that‘s also part of Nature. And we eat the bananas to stay healthy. And (…) we use the diamond. We sell diamonds to get money so we can live and eat more food to stay healthy and carry on living.	Useful; Helpful; Living	Bees/honey, bananas, healthy, diamond	Resource; Positive; Naturalistic
56.	R	How about this one: Do you think Nature is **frightening**?			
57.	S	I‘m not too sure. Oh, yes, yes. (Mmm.) Like that, m‘am. Like I‘d be scared to be in America and experience a tornado or hurricane and see my house blow up or something (Ja, for sure.) That‘s something frightening.	Frightening	Tornado, hurricane	Negative
58.	R	Okay. Do you think most of Nature is frightening?			
59.	S	No, m‘am. Like for vultures to eat meat, that‘s the way they survive. And…ja. I can‘t think of another example.	Not frightening; Purpose physical; Living	vultures	Neutral; Naturalistic
60.	R	So there are frightening parts in Nature…			
61.	S	But not all of it.			
62.	R	Okay, good. Do you think Nature is **just there**?			
63.	S	Yes. (Mmm.) Because, um, Nature, I don‘t think Nature started or it‘s going to end, it just was there all the time. We just weren‘t alive all that time.	Always there		Naturalistic

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
64.	R	And how did it…was there ever a beginning to Nature, did it start at one point, do you think, or has it always just been there?			
65.	S	Yes, m/am.	Always there		Naturalistic
66.	R	Do you think Nature is **over-used**?			
67.	S	Over-used…How do you mean by that, m‘am?			
68.	R	Um, in other words, is it used too much? Because you said we can use it like the diamond, the bee, the banana. Do you think we use too much of Nature?			
69.	S	No, because, the tree that gives us bananas (Mmm.) if it‘s been watered everyday, or watered often, then it will stay alive and give us more bananas.	Not over-used; Living; Useful		Resource; Naturalistic
70.	R	Ah, okay. Do you think Nature is **ruined**?			
71.	S	Yes, m‘am, because they cut trees down and then the banana‘s tree won‘t grow any more and give us more bananas.	Ruined; Man‘s impact negative; Cannot be repaired	Banana tree	Conservationist
72.	R	Okay, so it can be used in that we can take the bananas (Yes.) and as long as we keep watering it (yes) and looking after it (Yes, m‘am.) the bananas keep growing, but if we chop the tree down, then it‘s ruined. (Yes, m‘am.) Right.	Useful; Conserve; Man‘s impact negative; Ruined; endangered	Banana tree	Resource; Conservationist
73.	S	There won‘t be any more bananas.			
74.	R	Do you think Nature is **fascinating**?			
75.	S	Yes. (Mmm.) Because it‘s interesting to find out facts about Nature and things like that. Like, um, like with the diamond, m‘am, I never knew that the earth moves and stuff and that‘s how we get diamonds, and um…	Fascinating; Know/Learn	diamonds	Positive; Knowable
76.	R	Tell me about that?			
77.	S	Um, I don‘t think I‘m explaining correctly, but Mr. Bester said, or it was Mr. grant that said the earth moves (Ja.) and that gives us diamonds but it doesn‘t happen often.	Know/Learn	diamonds	Knowable
78.	R	Oh, wow.			
79.	S	That‘s fascinating for me.	Fascinating		Positive
80.	R	Do you think **we can see it and touch it**?			
81.	S	No. (Mmm.) I think we can only touch parts of Nature, like the animals and the cows and the bananas. But not the whole thing at once.	Physical	Animals, cows, bananas	Naturalistic
82.	R	Tell me about the parts that we can‘t touch.			
83.	S	Um, that (The student points to the picture of the tornado.) (Ja?) Otherwise we‘ll get sucked up (Mmm.) and, or we can‘t touch the lions because they‘ll eat us up. (Mm.) But most of it is not dangerous to touch. That is Nature…(unclear).	Physical	Tornado, lions	Naturalistic

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
84.	R	So the reason that we wouldn‘t be able to touch it is because it is dangerous.	Physical; Dangerous		Naturalistic; Negative
85.	S	Yes, m‘am.			
86.	R	Okay, lovely.			
87.	S	Do you think Nature is **spiritual**?			
88.	R	Uh, spiritual…			
89.	S	Is there a spiritual aspect to Nature, do you think? For you?			
90.	R	I‘m not too sure, m‘am. Can I leave this in the middle, m‘am?			
91.	S	Mmm/yes. We‘ll come back to it.			
92.	R	Do you think Nature **changes**?			
93.	S	Yes, m‘am. (Mmm.) because (…), like I said, m‘am, if they cut down the trees then there‘s less trees and then like the birds can‘t live in the trees so tat changes… like where would this nest be built if there was no trees? And if it‘s on the ground then these guys eat the eggs, or, or the lions eat the eggs and then there‘s no more birds.	Changes; Man‘s impact negative	Trees, birds, nest, eggs, lions	Unknowable; Conservationist
94.	R	And so the changes that happen and those caused by people?			
95.	S	Most of the time, m‘am.			
96.	R	Okay. Are they good changes or bad changes, normally?			
97.	S	I can‘t think of any good changes at the moment (Mmm.) No, I can‘t. I think it‘s all bad changes sometimes.			
98.	R	How about this one: do you think Nature is **powerful**?			
99.	S	Mmm, it‘s kind of difficult to answer, m‘am, because like these birds or those lions can eat us up but we can inject them with stuff and then we drug them and we can put them in a cage (Oh.) and so I don‘t know, m‘am.	Hurtful; Not dangerous	Vultures, lions, inject, cage	Negative, Neutral
100.	R	So, are you, kind, of, thinking of powerful in terms of dangerous?	Powerful; Dangerous		Negative
101.	S	Yes, m‘am.			
102.	R	Okay.			
103.	S	Or that like, say, when you feel that you just want to help somebody (Ja?) or when I look at the puppy (Ja.) and then that puppy has no food, I just want to feed him some beef or chicken to help him (Ja.) that is also kind of powerful. Mmm, I don‘t know…	Man‘s impact positive	Puppy feeding	Conservationist
104.	R	We can come back to this one too, if you want to…			
105.	S	I would say ―no”, m‘am, Okay), because, like, something like the bee, stings us, but then he dies but we don‘t come close to death. You know, stuff like that, m‘am.	Not dangerous; Hurtful	Bee sting	Neutral; Negative
106.	R	So powerful is kind of in relation to people.			
107.	S	I want to change it m‘am. (Okay.) Because the fire and that (the volcano) and that (The hurricane). You see because we can‘t stop that, m‘am but we can stop a lion from eating us. We can‘t stop a volcano (unclear).	Powerful; Dangerous; Not controlled	Fire, volcano, lion	Super-naturalistic; Negative; Unknowable
108.	R	So it‘s got to do with stuff that‘s possibly dangerous, and whether we can stop it or not (Yes, m‘am) from hurting us. Okay, I‘ve got you. Do you think Nature is **understandable**?			
109.	S	No, m‘am.	Not understandable	Dog‘s behaviour, digs holes	Unknowable
110.	R	Because?			

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
111.	S	Because sometimes I wonder, with my dog, I always wonder why does he do that? Why does he do this? And there‘s no real answer. He just does that weird stuff. And sometimes he just digs holes in the ground even if he has no bone (The student smiles. The interviewer chuckles.) So it‘s not really understandable for me.			
112.	R	What dog do you have?			
113.	S	German Shepherd			
114.	R	Ah, beautiful dogs. Is Nature **confusing** to you?			
115.	S	Yes. Like I said there, m‘am, I wonder why my dog does that, and it‘s also, m‘am, that he‘s got a ear problem, m‘am, so we keep on cleaning out his ear and we take him to the doctor and then his ear is fine again and afterwards his ear is funny again.	Confusing	Dog‘s ear	Unknowable
116.	R	Oh, really?			
117.	S	It goes on like that forever, m‘am. So it‘s confusing to me. (Ja.) Why doesn‘t it just stop? (The student smiles. The interviewer chuckles.)			
118.	R	Do you think Nature is **holy**?			
119.	S	I would say holy is like when you, um… (There is a pause while the student thinks.) I would say yes, m‘am, because say the lion is king of the pride, king of the jungle (Mmm.) but I never see vultures attacking the lions. I always see it the other way round. So I think they look up to the lions and I won‘t fight him unless I am a lion.	Holy; Orderly	Lion-King of jungle/pride, vultures	Spiritual; Knowable
120.	R	Gosh, that‘s a lovely example. Do you think Nature is **complicated**?			
121.	S	Yes! (Mmm.) Why does volcanoes erupts? Why does the hurricanes start? And why does fires happen and just grow and grow? And cause havoc? Havoc.	Complicated; Don‘t know; Chaos	Volcano, hurricane, fire	Unknowable
122.	R	Can we find out the answers to those questions, do you think?			
123.	S	No, I don‘t think so, m‘am. Because, like, the volcanoes just erupt because that‘s part of, um, Nature (Mmm.), you know, and the volcanoes [unclear] (The hurricanes.) The hurricanes, I don‘t know how they start.	Don‘t know	Volcano, hurricane	Unknowable
124.	R	Okay, great. Is Nature **ordinary**?			
125.	S	Ordinary, mmm… I forgot, I had an answer…No, no. (Mmm.) because like if I dress the normal way, the normal way to dress is top and jeans but like Nature is completely different to that. They‘ve got different styles, they‘ve got different styles of living. They don‘t just eat and drink water and now they can survive. They do other stuff, like, they kill other animals and stuff like that. And then they know, ―I‘m more powerful" and stuff like that, m‘am. So it is quite strange.	Unusual; Mixture of different things; Living; Nature kills; Orderly	Dress—jeans&top, lifestyles, survive, kill	Naturalistic; Resource; Negative; Super-naturalistic; Unknowable; Knowable
126.	R	So is it because they do more of a variety of different things?	Mixture of different things		Resource
127.	S	Yes, m‘am.			
128.	R	Okay. Do **we need it**?			
129.	S	Yes! We kill the lions or the cows to get meat, and eat the meat and then we can survive. Or we kill the chickens, you know, and to get the meat and then we can survive, so we do need Nature, and the milk for our porridge in the morning.	Need it	Cows-meat/milk, chickens	Resource
130.	R	Okay. Do you think Nature is **predictable**?			

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
131.	S	What does that mean, m‘am?			
132.	R	Predictable. Can you tell what‘s going to happen in the future?			
133.	S	Yes, because like people say that in 2012 there‘ll be another eclipse where you see Venus come over the sun, so they say that will happen, they say the next time it will happen is like in the 21st thousand years or something like that. (Okay.) So, yes, m‘am.	Predictable	Venus eclipse	Knowable
134.	R	Now that‘s an interesting example. Do you think Nature is **mysterious**?			
135.	S	Mysterious…I don‘t know, m‘am. Mysterious. M‘am can you give me an example, please, of the word mysterious?			
136.	R	You must give me an example of the word mysterious! In other words, um, things that might happen in Nature and you think, ―Aw, that‘s a mystery to me.” Or do you think, you know, ―No, it‘s not a mystery.” There aren‘t these big questions, you know…			
137.	S	No. I‘d say no, m‘am.	Understandable		Knowable
138.	R	Because?			
139.	S	Because, like I said, m‘am. They eat each other to survive and it‘s not too mysterious for me because that‘s the way they live. And we get used to it, m‘am.	Purpose physical; Understandable; Living		Naturalistic; Knowable
140.	R	Okay. Do you think Nature is **beautiful**?			
141.	S	Um, yes, m‘am. (Mmm.) because when I take pictures of, when we go to the Kruger National Park and then we saw the trees and the road and then there‘s like a (unclear) and then it looks beautiful, the whole picture. (Ja.) And like that (The student points to the picture of the puppies and kitten.) all of them in a basket. (The student smiles and the interviewer laughs.)	Beautiful	Kruger National Park photos, puppies	Positive
142.	R	Do you think Nature is **pure**?			
143.	S	Pure, um, no. (Mmm.) because… do you mean pure like they don‘t do anything wrong? (Mmm/yes.) M‘am it‘s not pure because they kill each other and stuff like that and they, mmm, I don‘t know, m‘am. I would go with no, because they kill each other. Like the lions, they just kill the other lion and so they can be king of the jungle (okay.) they fight over who‘s the king. That‘s not pure. That‘s cruel.	Nature kills; No function/ purpose; Unappealing	Kill; lion/king of jungle	Negative; Naturalistic
144.	R	Is it a **mixture of different things**?			
145.	S	Yes. (Mmm.) Let me think of an example… Nature, yes it is, m‘am, because like this bee, he gets honey from a flower and he puts it in the hive and, um, what a cow does he eats and then he gives us milk. And they always, every animal has got a different part, role, they eat this thing and they wait for another two days for another animal.	Mixture of different things; Purpose physical; Useful	Bee/honey, flower, cow/milk	Resource; Naturalistic
146.	R	Okay, that‘s a lovely example. Now do you want to go back to **spiritual** and think about that one?			
147.	S	Spiritual… No, m‘am. Because if I had to think about spiritual I think about people like putting in spices and maybe a live cow and then they throw the cow on the fire and then the fire goes big and then they all sing a song and play the drums, but I don‘t see animals doing that.	Not spiritual	Ritual/sacrifice	Naturalistic

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
148.	R	Okay, fantastic. Okay, now what we‘re going to do is we‘re going to take these ones that you say Nature is like that, we‘re going to start with these first (…) and see if there are any of these that maybe belong together in groups. (Okay.) and then group them together for me. So you can move them around and reorganize them. There might be some that stay on their own and that‘s fine.			
149.	S	Like would this be a pair, m‘am? (i.e., ―can be used” and ―we need it”)	Useful; Need it		Resource
150.	R	Ja, so now you can tell me why you think those two go together.			
151.	S	Because we can like take off the bananas from the tree, and we eat it, and we need that bananas to stay strong and healthy.		Bananas, healthy	
152.	R	Okay, so it ―can be used” and ―we need it” go together.			
153.	S	Yip.			
154.	R	Perfect. Are there others that maybe go together?			
155.	S	(Holy and Powerful are grouped together.) Um…like I said, m‘am, I don‘t see a vulture attacking a lion because the lion‘s powerful so they won‘t fight with you.	Powerful	Vulture, lion, king of the jungle	
156.	R	And the holy bit?			
157.	S	They won‘t fight with the lion because he‘s powerful.	Holy; Orderly		Knowable
158.	R	Okay. Are some parts more holy than others, do you think?			
159.	S	How do you mean, m‘am?			
160.	R	So are the ones that are more powerful more holy?			
161.	S	No, m‘am… this, he‘s (The lion) is a powerful animal so he won‘t fight with him.	Orderly		Knowable
162.	R	Okay.			
163.	S	(A mixture of different things and Confusing are grouped together.) Confusing. I think because Nature‘s also filled with a lot of different things that also makes it confusing.	Mixture of different things; Confusing.		Resource; Unknowable
164.	R	Okay.			
165.	S	I can‘t give you an example.			
166.	R	That‘s okay. That makes sense to me.			
167.	S	Okay, um…it changes (Mmm.) like, um…			
168.	R	Is ―it changes” going with ―complicated”?	Change; Complicated		Unknowable
169.	S	Yes, m‘am.			
170.	R	Okay.			
171.	S	Like, because, probably, I would say, five years and the volcano stays the same, and then it just blows up all of a sudden. And it changes because it just blows up. (Mmm.) Why does it just blow up all of a sudden? (Mmm.) Okay, I think these two go together.	Change; Don‘t know; Unpredictable	volcano	Unknowable
172.	R	Frightening and ruined?	Frightening; Ruined		Conservationist

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
173.	S	Because if you like chop all the trees down, and then maybe at the end of the year we chop down maybe a million trees from one forest, and we say,, ―Oh, there‘s no more trees," and we go look to that, we go back to that forest, look at it, we see, ―What have I done? I‘ve ruined like that part of land." And we did something wrong.	Man‘s impact negative; Ruined	Chop trees	Conservationist
174.	R	So how does frightening fit into that? With that ruined?			
175.	S	What have I done? I… because they chop all the trees down from that one part, from one forest, then they will see, ―Ah, what did I do now? This is just a whole lot of sand. There wasn‘t the beautiful trees that was here."	Frightening; Ruined Man‘s impact negative; Beautiful	Chop trees, consequences	Conservationist; Positive
176.	R	So you‘re frightened now of the consequences of what‘s happened because of what you‘ve ruined it? (Yes.) Okay. (…)			
177.	S	(There is silence while the student considers how to group the remaining ―Nature is" words.) They don‘t have to, if they don‘t fit, or if some of those fit in there you can join them up…			
178.	S	Like three?			
179.	R	Ja!			
180.	S	Oh!			
181.	R	Or four or five, you can have big groups.			
182.	S	I dunno, m‘am. Oh, yes, here we go. These two.	Orderly; Predictable		Knowable
183.	R	Orderly and predictable, ja?			
184.	S	Like I said, like, I think it was 2004, no, 2005, when the, when Venus crossed the sun (Mmm.) and they said it will happen again. There must be some order that they found out that it will happen again in 2012.		Venus eclipse	
185.	R	Okay.			
186.	S	Mmm, and I think these will just be like this. (i.e., the remaining words stay as is.)			
187.	R	And do any of these groups link up?			
188.	S	No, m‘am. I don‘t think so.			
189.	R	Okay, good. So you are happy with them like that?			
190.	S	Yes, m‘am.			
191.	R	Okay, now I need to stick them on here so I can remember them…(The interviewer takes out a sheet of blank paper.) if you were to choose one group to say to me, right, this is the first group I was to talk about if I was to explain to you about Nature, this the group that I would tell you about first. Which one would it be, do you think, out of those?			
192.	S	These ones, m‘am.			
193.	R	Frightening and ruined. Why do they come in first?	Frightening; Ruined Man‘s impact negative; Beautiful; Need it	Chop trees, consequences, paper	Conservationist; Positive; Resource
194.	S	Because, um, Nature is, aaah, I think beautiful will go with this.			
195.	R	Beautiful? Ja, tell me about this.			
196.	S	Um, because, m‘am. I would say like Nature is a beautiful thing, m‘am, and then because we have to like have paper to write on and then they just chop down all this trees and then they chop down all the beautiful trees and plants and then it‘s they look afterwards and say, ―What have I done? I‘ve just chopped down this forest."			
197.	R	Oh, okay, ja. Gosh, that‘s a good explanation. What would come in second, do you think?			
198.	R	(The student point.) It changes, and complicated?	Changes,		Unknowable

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
199.	S	Complicated, it changes.	complicated		
200.	R	Now why does that come in second?			
201.	S	(Unclear). I would take holy, holy.			
202.	R	Holy and powerful next?	Orderly		Knowable
203.	S	Yes, m'am.			
204.	R	Okay, tell me about that.			
205.	S	Because, like, um, like a school, m'am. When you have a school and that's number one, and then after that comes the principal who controls that school, also like, it's the jungle and afterwards comes the animals who are controlling, if that makes sense.	Orderly	Hierarchy, status, school/jungle, animals control	Knowable
206.	R	So it's also like a status thing, like a hierarchy? Like, who's at the top?			
207.	S	Yes, m'am.			
208.	R	Okay.			
209.	S	Mmm… (…)			
210.	R	What's the next most important thing for you about Nature?			
211.	S	Uh, orderly, predictable (Mmm.) Ah, why would I put that third? Ah, because, um, Nature does work in a order, like they kill to eat so they can survive, um, and then like this, m'am, these vultures eat this animal, they eat all the meat off it and then the hyenas come and they eat the bones and they, then, like, everybody's surviving.	Predictable; Orderly; Nature kills; Purpose physical	Vultures, hyenas	Knowable; Negative; Naturalistic
212.	R	Brilliant. What comes in fourth, do you think?			
213.	S	Uh, complicated, changes. (Mmm.) I would say changes comes fourth, m'am, because…I don't know why, m'am, it just feels right to put it number four (Okay.) but I don't know a reason why, m'am.	Complicated; Change		Unknowable
214.	R	And do you think that although it is orderly, there are still changes that happen?	Orderly; Change		Knowable; Unknowable
215.	S	Yes, m'am.			
216.	R	Okay and then you were saying that the changes are mostly because people get involved.	Change; Man's interaction		Unknowable; Resource
217.	S	No, not always, m'am…			
218.	R	Not always, just some of them…			
219.	S	Like volcanoes…		volcano	
220.	R	Right, so the volcano can also change, which is why it's complicated.	Change; Complicated; Don't know		Unknowable
221.	S	Or like, here's also an example, like say there's every five years a volcano will erupt, but what if it happens, what if it changes to six years? (Okay.) You know, why will it change?			
222.	R	Okay. Super. Now what about these. We've got two groups and two single ones left.			
223.	S	Oh, this.			
224.	R	Can be used, and, we need it. Okay?	Useful; Need it		Resource

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
225.	S	That comes because, some part of life we must think of ourselves, so we, ja, like we need the banana to eat, and diamonds to sell to get money, and this last. Is this last m‘am?	Need it; Useful	Banana, diamonds	Resource
226.	R	It‘s up to you.			
227.	S	Okay, then I‘ll put…			
228.	R	Okay, a mixture of different things and confusing. Okay, why do those come next after ―can be used” and ―we need it”?	Mixture of different things; Confusing		Resource; Unknowable
229.	S	Um….uh…no, I don‘t know why. I forgot what I was thinking last time… mixture of different things…			
230.	R	Uh, last time you mentioned like the bee makes honey, the cow makes milk…	Mixture of different things	Bee/honey, cow/milk	Resource
231.	S	Ah, yes, and it‘s confusing like, like, um, maybe the cow and the vulture are the same size but they do different things, like completely different things. Like he (i.e., the cow) doesn‘t go near to killing things, he just eats the grass, (Mmm.) but they (unclear).	Mixture of different things; Confusing; Purpose physical; Not dangerous	Cow/grass, vulture	Resource; Unknowable; Naturalistic
232.	R	Interesting example. And of these two ones that are left, which one goes next?			
233.	S	Uh, just there.			
234.	R	Just there, okay, why does this one go next?	Just there		Neutral
235.	S	I don‘t know, m‘am. Uh, just there…oh because, I think that there was no beginning to Nature. I thought it was just there and I don‘t think it‘s going to end unless this earth blows up, goes into a black hole, then I believe that‘s the end.	Always there; Reliable	Blows up, black hole	Naturalistic; Neutral; Reliable
236.	R	Do you think that might happen?			
237.	S	Yes, m‘am, because our teacher says in science that scientists like say that the sun is going to blow up or it is going to fall into itself. Or the earth is going through the same thing but in one billion years (Really.) that‘s quite a long time	Change; Predictable	Scientists predict; Sun/blow up	Unknowable; Knowable
238.	R	Do you think that‘s going to happen? Are you going to trust what they tell us?			
239.	S	No, m‘am, because when I go to church, m‘am (Ja.) and they sing a hymn, and it says, like the last line says, ―world without end” and it goes ―amen.”	Reliable	Church vs. school science, Don‘t believe scientists. *Conflict between religious beliefs and what is taught in science at school.*	Resource
240.	R	Ah, okay.			
241.	S	So, yeah, so I think if God says there will be no end I think that‘s the right. I don‘t believe the scientists.			
242.	R	Okay.			

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
243.	S	Because every time in science when we talk about a different subject then Mr. Bester always uses scientists as example, but scientists aren‘t super-humans (Ja.) they also make mistakes, so maybe they‘re wrong about the world ending.	Don‘t know	Scientists make mistakes	Unknowable
244.	R	Okay.			
245.	R	Where do they get their ideas from that the world‘s going to end?			
246.	S	Um, I don‘t know, m‘am. Because maybe the scientists like to think that everybody says that good things come to an end. Like when you party it‘s going to come to an end some time, then you got to go to work so maybe they‘re using that.	Predictable; Know/Learn	Scientists‘ ideas	Knowable
247.	R	Okay. Now let‘s look at these ones that you said Nature is not like that. So now these are ones that you said you disagree with. Do some of those fit into groups? You might think maybe they stay on their own. (The student asks what the time is and he is very surprised.) Has it gone quickly?			
248.	S	Yes, m‘am! (There is silence while the student thinks about the remaining —Nature is not” words.) I don‘t know, m‘am, which go together.			
249.	R	Do you think they are all separate?			
250.	S	Yes, m‘am. But maybe I can form a group…			
251.	R	You don‘t have to form a group if you don‘t want to.			
252.	S	(There is silence while the student continues to think about the remaining —Nature is not” words.)			
253.	S	I don‘t know, m‘am.			
254.	R	Which one would you, if you choose one to talk about first…We‘re going to do the same kind of process?			
255.	S	Okay. Um, so we‘ve finished with the —is”, m‘am?			
256.	R	Ja. All the —is” ones are there.			
257.	S	Okay.			
258.	R	So in other words, which of those do you think is the most wrong, that Nature is not? Or, which one would you want to talk about first?			
259.	S	Understandable.	Understandable; Explainable; Not over-used; Reliable; Useful		Knowable; Resource
260.	R	Okay. Mmm. Why does this one go first?			
261.	S	Because, like, um, there‘s some stuff there that we can‘t give an explanation for, and one is about Nature. Um, and second I would say…would be…not over-used (Mmm.) because if we don‘t chop down then there will always be food and cows and everything that gives us food.			
262.	R	Okay, brilliant			
263.	S	Um, like, to me Nature is not mysterious (Mmm.) because…Nature is not mysterious because…mmm… Nature is not mysterious because…I don‘t know what‘s the reason why I put this in…oh, yes, some changes, um, we do understand (Ja.) but some is, we don‘t understand, yeah, so like most of Nature‘s works doesn‘t come as a surprise. It‘s not strange.	Understandable; Changes		Knowable; Unknowable
264.	R	Okay. What‘s fourth?			

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
265.	S	Fourth…mmm… Nature‘s not pure, because like what I said before, because like I said before the lion will just kill another lion just so he can be on the top, but even if we just stay at the bottom (unclear.) Yes, people just kill each other…like, say this lion killed this animal, he just left him laying there, he probably didn‘t even take a bite, just drag him to the den and now these vultures found the body and now they eat it.	Nature kills; No function/purpose	Lion; hierarchy/king of jungle	Negative; Naturalistic
266.	R	Okay.			
267.	S	So that lion probably killed that thing for no reason, just because he wanted to kill. (Okay.) He wanted a little snack and then he just left it there.	No function/purpose		Naturalistic
268.	R	Good example. What‘s next?			
269.	S	Ordinary. Nature‘s not ordinary. (Mmm.) Um, because there‘s things that happen in Nature that‘s quite strange. Like, what did I say, quite strange…like, uh…oh, yes, like this desert. (Ja.) How did all that sand get there? It‘s not like simple. (Ja.) Like simple and ordinary, same thing. Like you see like a whole place full of sand is quite strange to see. And this stuff, like when I look at a jellyfish, you know, I just see this thing, because, it looks quite strange (Mmm.) and all the animals look quite strange because they all play different parts in, uh, in their lives.	Unusual; Don‘t know		Negative
270.	R	Good.			
271.	S	I think that makes sense.			
272.	R	Ja, that makes sense to me. What‘s next?			
273.	S	Um…I think this one.			
274.	R	Uhu, that we can‘t see it and touch it?	Physical		Naturalistic
275.	S	Yes, m‘am.			
276.	R	Okay. Why‘s this the next one?			
277.	S	Oh, I was answering the wrong question, m‘am.			
278.	R	What?			
279.	S	Oh, no,, uh, I would say we can‘t see it and touch it because, like, how big is a jungle, m‘am, like a really huge jungle like the Amazon? How big is the Amazon?		Amazon Jungle	
280.	R	Ja, it‘s, I mean I think it will span acres.			
281.	S	M‘am, you see, m‘am, you can‘t touch the whole Amazon at once. Can‘t see it. We can see it, we can‘t touch it all at once.			
282.	R	Okay.			
283.	S	Unless we are like high up (Right.) and we can see all of it. But if we‘re in the Amazon we can‘t see all of it and touch it at once.			
284.	R	Okay, good example. Interesting example? And then spiritual comes in last.	Not spiritual	Sacrifice cows & humans	Naturalistic
285.	S	I don‘t know why. That comes in last…it, like I said, m‘am, when I think of spiritual people, I think of they sacrifice cows and sacrifice humans and put them on a pole and they just put oil all over them and they just burn up.			
286.	R	Okay, super. Can we do the last thing?			
287.	S	Last thing, okay, m‘am!			

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
288.	R	It‘s sentences. Some of them you might agree with and you‘ll say, ―Yes, Nature‘s like that (The interviewer places the caption ―Yes/Agree” on the desk.) And some of them you might say, ―I disagree, Nature is not like that.” (The interviewer places the caption ―No/Disagree” on the desk.) (Okay.). Okay. Um, let‘s start with this one: Do you think **Nature is dangerous?**			
289.	S	Yes, I agree with that one. Because, like, if I use dangerous terms, this animal will eat me up and that‘s quite, I‘ll get scared of that (The lions.) Yes, m‘am, because they, some of them are bigger than us and I‘ll be scared for that, some of that‘s quite dangerous.	Dangerous; Frightening	lion	Negative
290.	R	**Without the things we get from Nature, we could not enjoy the everyday life we have today.**			
291.	S	Um, let me think if something…yes, no, yes, like, let me just say the banana. If we‘re gonna eat a banana, well then have a banana in our life, then we won‘t have so much energy and we won‘t be so fit and strong and so then we can‘t run around and play soccer and play cricket and all that, rugby, and…	Useful	Banana, energy, healthy, sport	Resource
292.	R	That‘s a good explanation. **The natural world is all there is, all there ever was, and all there ever will be.**			
293.	S	Um, I don‘t know where to put that, m‘am. (The student re-reads the statement to himself.) I don‘t know, m‘am.			
294.	R	You can break it up if you want to. You can talk about if you think it‘s all there is…			
295.	S	I‘ll say, no, m‘am.			
296.	R	Okay, because?			
297.	S	Because, like this is Nature, m‘am, but there‘s still lots more that that, there‘s people that‘s not on here, okay, there‘s guys there, there‘s people, there‘s cars, you see we can‘t…we don‘t just play with Nature, we do play with technology and all of those things. (Okay.) So…	Technology	People, cars, technology	Naturalistic
298.	R	And do you think Nature is all there ever was?			
299.	S	No. Oh, maybe. Like, m‘am, if I break it up, like Nature is all there ever was, then I‘ll say the technology part, but now if I think…	Technology	People, cars, technology	Naturalistic
300.	R	No, no, that‘s fine, we can talk about each part and if there‘s some that are yes and some that are ―no” then we maybe put it in the middle.			
301.	S	Oh, yes, m‘am, because it says… (The student re-reads the statement again to himself.)			
302.	R	So the first bit you think ―yes”, I mean, the first bit you think ―no”.			
303.	S	(The student re-reads the first part of the statement again to himself.) No.			
304.	R	Okay. Is it all there ever was?			
305.	S	Yes, m‘am, because, like, before we were born, or maybe before Earth was created, there was the universe with lots of planets and all that and we didn‘t create that planets, it was Nature. The gas and all of that, the planets.	Always there; Created	Universe, planets, gas	Naturalistic; Super-naturalistic
306.	R	Okay. And do you think it is all there ever will be?			
307.	S	I think Nature will always be there, m‘am, like the planets. Like we can die but the planets will still be alive. The earth can go into a hole but then there‘s still another five hundred million planets still alive, still there.	Reliable; Living	Planets, black hole	Resource; Naturalistic
308.	R	So then maybe what we do, is we bracket off this first bit and then it goes…or do you want to keep it in the middle group because it‘s a mixture of both?			
309.	S	Okay.			
310.	R	Okay. **I view Nature as something solid, large, and reliable.** Do you agree or disagree?	Reliable;		Resource

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
311.	S	Disagree. (Mmm.) Because, like, this puppy m‘am. He‘s not large, and he is solid, m‘am, but he‘s not large. And reliable…	Useful	puppy	
312.	R	Do you think we can rely on Nature?			
313.	S	Yes, m‘am. Apples, bananas, fruit all come from Nature.		Apples, bananas, fruit	
314.	R	Do you like eating fruit?	Likeable; Useful		Positive; Resource
315.	S	I love it! (Mmm.) I like mangoes.			
316.	R	Mmm, so do I.			
317.	S	Ja, so that‘s also created by Nature, but, uh, I think all food‘s created by Nature, by the cows… the fire that we cook our braais which is the meat and all that stuff. So I would say that do need it.	Created; Need it	Food, cows, braai/fire, meat	Naturalistic; Resource
318.	R	Alright, yes. **I am worried about the pollution and the damage it does to Nature.**			
319.	S	(The student reads the first part of the statement aloud to himself.) Yes, m‘am, I am worried, m‘am. (Mmm.) like I said, like, if we cut down trees there won‘t be any fruit because… is there fruit that grows on the ground?	Polluted; Endangered; Man‘s impact negative	Fruit trees	Conservationist
320.	R	Um, watermelon grows on the ground, like on a creeper. (Watermelon.) A pumpkin also grows on the ground. (Oh.) But mostly it grows on bushes or trees.			
321.	S	Okay, so then if they cut down the bushes and trees it will just be watermelon and pumpkin, and that wouldn‘t be nice to eat that the whole day, m‘am. (The student laughs.)	Mixture of different things; Useful; Likeable	Edible vegetation	Resource; Positive
322.	R	**Nature can be repaired?**	Cannot be repaired	Dog, tree	Conservationist
323.	S	No, m‘am. Like if this dog dies, you can‘t put him back to life. If they cut down a tree, we can‘t sew it on again. It will just be off and that‘s the end of it.			
324.	R	Ja. **I enjoy Nature?**			
325.	S	Yes, m‘am. In like Nature. I like experiencing or going to the jungle and seeing an elephant walk past the car or lion walk passed the car. Or I like to see a lion roar (Mmm.). Like if I see it on TV it won‘t be so amazing but if I‘m there, like maybe next to the lion or a couple of feet in front of it, it will be amazing for me. Or see a volcano erupt (Ja.), but I would get out of the place! (The student smiles and the interviewer laughs.)	Likeable; Amazing; Observe; Dangerous	Jungle, elephant	Positive; Knowable; Negative
326.	R	**There is chaos in Nature.**	Chaos	Lion chases dog	Unknowable
327.	S	Chaos? Yes. (Mmm.) like, like, this dog. If he‘s walking alone on the road and he sees this lion he‘s going to try and run way and they‘re going to try and eat him so there‘s chaos.			
328.	R	Okay. Do you think **Nature should be studied so that we can learn more about it?**			

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
329.	S	Yes, m‘am. (Mmm.) like for instance, that‘s why we have science, m‘am. So we can, Natural Science, so we can learn more about Nature so then there‘s more stuff we know about it, like, like if I wasn‘t told about the solar system, m‘am, I wouldn‘t have known about it. because then I wouldn‘t have known…like now I‘d go on Google, we‘re doing a science project, and I‘d go on ~~-n~~ine planets” and then it will come up, but I wouldn‘t know there was such a thing if nobody told me (Okay, right,) if I wasn‘t taught about it.	Know/Learn; Discover	Natural Science lessons, solar system, planets project/Google	Knowable
330.	R	And how else do you suppose it helps us if we study it?			
331.	S	Um…I don‘t know, m‘am. Oh, yes! Like the diamonds, m‘am. Because we need money, m‘am, so we can buy food, stay healthy. And then if we didn‘t study about the earth we wouldn‘t know how diamonds was created and stuff like that (Okay.) We wouldn‘t know about diamonds.	Need it; Useful; Know/Learn; Created by Nature	Diamonds, money, food, healthy	Resource; Knowable; Naturalistic
332.	R	There was another question that I thought of that I wanted to ask you about…because you gave such a nice example about the planets…oh, I wanted to ask you where else you found, because all that you know about Nature, it seems like some of it comes from your science lessons (Yes, m‘am.) where else have you learnt what you know about Nature?	Know/Learn; Purpose physical	Science lessons, fynbos, fire	Knowable; Naturalistic
333.	S	Um, I would say all of it was from science lessons (Ja.) Because they, Mr. Grant, which used to be my old science teacher, used to say that, he used to talk about the fynbos and that that fynbos needs fire to survive (Okay) and so it has seeds in its leaves and when it burns it goes to the ground and then it makes more fynbos.			
334.	R	Ja, okay. Oh, super. Not many more. **There is more to Nature than what we can just see and touch.**	Physical; Know/Learn & Don‘t know		Naturalistic; Knowable/ Unknowable
335.	S	Yes, m‘am, like a tree. Like, um, let‘s say, if you just see a tree as its full growth, we wouldn‘t know that it was this small and then grow and grow and grow, and we wouldn‘t know, um, that it needed water to get as big as it is when we saw it as full growth.			
336.	R	That‘s such a nice example, good. (…) **Do you think things happen in Nature for a purpose?**			
337.	S	Um…ja! (Mmm.) like the lion, well, she goes and hunts for food and then she brings it back to the house where the little cubs are—is cubs the right word, m‘am?(Um, ja.)—baby lions (Ja, cubs.) and they feed it to the little lions so they survive so they can dig so they can hunt for themselves.	Purpose physical; Living	Lioness feeds cubs	Naturalistic
338.	R	Brilliant. **Nature is an everyday part of life that I normally do not think much about.**			
339.	S	If I think about food, m‘am. (Mmm.) I would need food to survive and food only comes from animals and plants and stuff like that (Okay.) so I would be like, and I would be like falling asleep if I didn‘t have any food. (Ja.) Or I‘ll be dead. Or I‘ll, close to death.	Think; Need it	food	Resource
340.	R	Do you think about food a lot?			
341.	S	Yes, m‘am.			
342.	R	Are you hungry a lot?			
343.	S	Yes, m‘am.			
344.	R	Because you‘re a young, growing boy! **I believe Nature needs to be protected.**			

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
345.	S	Yes, m‘am because the hunters that want money for paper, like they give trees, to , I think the factory, m‘am, (Mmm/yes.) or somebody, and then they give them money so they can make paper to give to schools and stuff like that. I think that they should cut up like a small part of a jungle each month, not the whole jungle at once.	Useful; Man‘s impact negative; Conserve	Hunters, money, paper, factory, trees, jungle	Resource; Conservationist
346.	R	Oh, right, okay. (…) **In Nature I see the work of God?**	Created	Teachers‘ tricks	Super-naturalistic
347.	S	Yes, m‘am, because, mmm… like, I wouldn‘t say, like of somebody told me, like, say Mr. Bester was playing a trick on me and he said, “Dean, do you know that my friend‘s name is John and he made a bee.” And I would say, “No, Mr. Bester, I don‘t believe you.” Or, “He can make bananas with his hands” (The interviewer laughs) I wouldn‘t believe that. If they say that, because a lot of people say that God was here before us (Ja.) and so I would believe it if they said, like, he created all this stuff (Okay.) and he made people and stuff like that.			
348.	R	Okay, super. And this is the last one: **Nature is difficult to understand.**	Understandable; Know/Learn; Predictable	Learn, not a shock	Knowable
349.	S	No, m‘am, because if we learn about certain parts of Nature, and then it will, it wouldn‘t come to a shock to me, it wouldn‘t be difficult to understand because I‘ve learnt about it.			
350.	R	Okay, super.			
351.	S	But if I haven‘t learnt about something then it would be confusing.	Don‘t know; Confusing		Unknowable
352.	R	Right, which is what you were saying here.			
353.	S	Ja.			
354.	R	Great. Okay, now what we‘re going to do is I‘m going to give these to you two at a time, so you can compare two and you keep the one that you feel is strongest “yes”.			
355.	S	Okay.			
356.	R	So I‘ll start with these two: **I enjoy Nature**, or, **there is more to Nature than what we can just see and touch**. Which do you agree with most strongly? (The student chooses to keep the second statement, i.e., there is more to Nature than what we can just see and touch.) So, keep that one and put this one up here.	Physical		Naturalistic
357.	S	Okay. Now, compare this one with that one: In Nature I see the work of God, or, there is more to Nature than what we can just see and touch. (The student keeps the first statement, i.e., In Nature I see the work of God.) Okay, Nature is an everyday part of life that I normally do not think much about, or, in Nature I see the work of God.	Spiritual		Super-naturalistic
358.	R	(The student laughs.) M‘am, it‘s funny to see now, m‘am, because when I look at that, m‘am, then I must (unclear)…(The student rereads the last statement aloud to himself.)			
359.	S	That should go on the other side, shouldn‘t it? Because you were talking about food.	(Think) Useful	Food	Resource
360.	R	Yes!			
361.	S	Ja, so put that that side.			
362.	R	Okay. I view Nature as something solid, large, and reliable, or, in Nature I see the work of God. Which do you think is more strongly “yes”?			
363.	S	(The student rereads the new statement aloud to himself.) I don‘t know m‘am…(There is silence while the student decides which statement to keep.) (The student keeps the previous statement, i.e., in Nature I see the work of God.)	Spiritual		Super-naturalistic
364.	R	Okay. Nature is dangerous, or, in Nature I see the work of God?			

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
365.	S	Mmm, m‘am, if I think about it, if you like, this is what my ma normally tells me everyday and I believe my mom because she says like if you pray a lot and you thank god for your food and you don‘t just take it, take your food and don‘t say thank you, then, like, if a lion must come to your house one day, then my ma says God will put the barrier around you (Ja.) and the lion won‘t interfere with you (Okay.). Maybe…	Spiritual; Dangerous	Pray, God protects/barrier	Super-naturalistic; Negative
366.	R	Do you want to put that on the other side then?			
367.	S	Yes, okay, then.			
368.	R	Is that what you are saying? (The student nods.) Ja, okay. I am worried about the pollution and the damage it does to Nature, or, in Nature I see the work of God?			
369.	S	(The student rereads the new statement aloud to himself.) What is this m‘am? I don‘t really, like, get this one, m‘am.			
370.	R	Um, do you think Nature is polluted?	Polluted		Conservationist
371.	S	Yes, m‘am,			
372.	R	And then so are you worried about that? And what its effect is on Nature?			
373.	S	Yes. Yes, m‘am, I‘m worried. (The student keeps the new statement, i.e., I am worried about the pollution and the damage it does to Nature.)			
374.	R	More that you are thinking that…alright, good. Without the things we get from Nature we could not enjoy the everyday life we have today. So it‘s that one, or, are you more worried about the pollution and the damage it does?			
375.	S	I‘m trying to think of something for this, m‘am. (The student rereads the new statement aloud to himself.) M‘am, if I think about soccer (Mmm.) then I would say there‘s grass, or if I think about cricket, you need grass and then that grass help us play the sport. (Ja.) Because if there‘s just sand it wouldn‘t be such an easy game.	Need it	Grass sportsfields	Resource
376.	R	Good. How about this one: Things happen in Nature for a purpose, or, that we use Nature for things we need everyday?			
377.	S	I would still go with this one (i.e., Without the things we get from Nature we could not enjoy the everyday life we have today.)	Need it		Resource
378.	R	Mmm. I believe Nature needs to be protected, or, without the things we get from Nature we could not enjoy the everyday life we have today.			
379.	S	(The student rereads the new statement aloud to himself.) Yes, m‘am, because like, I think, these, if I had to choose a group, these two go together, m‘am (Okay. Because I must protect Nature so that I can have…). So I‘ll still go with this one (i.e., I believe Nature needs to be protected.)	Need it; Conserve		Resource; Conservationist
380.	R	Super. There is chaos in Nature, or, I believe Nature needs to be protected.			
381.	R	Super, so this one (i.e., I believe Nature needs to be protected.) goes top.	Conserve		Conservationist
382.	S	Okay, so now if we did the same thing with these ones?			
383.	R	Which is the stronger ―no”?			
384.	S	Ja.			
385.	R	Okay.			
386.	S	So now, these are things that are wrong. (..) Nature is dangerous, okay… (Okay.) Nature is difficult to understand. Which one do you disagree with the strongest? (The student selects the second statement.) That it‘s more difficult to understand? That‘s more wrong?			

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
387.	R	*This* one is more wrong (i.e., Nature is dangerous.)			
388.	S	*This* is more wrong, well then keep that one (i.e., Nature is dangerous.).			
389.	R	Okay.			
390.	S	Nature can be repaired, or, Nature is dangerous? Which is more wrong? (The student keeps the first statement, i.e., Nature can be repaired.)	Cannot be repaired		Conservationist
391.	R	This is more wrong?			
392.	S	Yes, m‘am.			
393.	R	Okay, keep that one. Nature is an everyday part of life I normally do not think much about, or Nature can be repaired?			
394.	S	This is still more wrong (i.e., Nature can be repaired.)	Cannot be repaired		Conservationist
395.	R	Good. Nature is something that should be studied so we can learn more about it? That was supposed to be on the other side, wasn‘t it? (The student and the interviewer both laugh.)	Know/Learn	Planets	Knowable
396.	S	I think so, m‘am!			
397.	R	It *was*, hey? Because you said that we need to…			
398.	S	Oh, yes, about science and the planets…			
399.	R	Ja…			
400.	S	Okay, so this comes top of the list here…			
401.	R	Yes, m‘am.			
402.	S	Now can I ask you a funny thing… without going through the whole process…we can either do this again, repeat this side, or otherwise, you can compare it with some of these and tell me, for example… no, maybe we just compare it with the top one.			
403.	R	Okay. So let‘s say, do you feel more strongly that Nature needs to be protected, or, do you think more strongly that it is something that should be studied so we can learn more about it?			
404.	S	I think this one (i.e., Nature is something that should be studied so we can learn more about it.) will go to the bottom.	Conserve		Conservationist
405.	R	Okay, great. Super. Perfect.			
406.	R	Okay, so is there anything else before we finish off? Because basically we, all I‘m going to do is stick these on a piece of paper…			
407.	S	Okay, I want to change this, m‘am.			
408.	R	Do you want to change the order now? (Ja.) Good.			
409.	S	Like that. (The student adjusts the order of the statements, so that ―In Nature I see the work of God” is placed second.)	Spiritual		Super-naturalistic
410.	R	Okay, so strongest is that Nature needs to be protected?	Conserve		Conservationist
411.	S	Yes, m‘am.			
412.	R	And second strongest is that you see the work of God in Nature.	Spiritual		Super-naturalistic
413.	S	Yes, m‘am.			
414.	R	And then are the rest in order as well, or is that just rest random?			
415.	S	The rest is random.			

REF	ID	INTERVIEW TEXT	CODES	EXAMPLES	CLASSIFICATION
416.	R	Okay, so these are the most important two. And which was the one that needs to go together with this one, that it needs to be protected?	Conserve; Need it		Conservationist; Resource
417.	S	Oh, it was…			
418.	R	That one?			
419.	S	This one (i.e., Without the things that we get from Nature we could not enjoy the everyday life we have today.)			
420.	R	So should we stick this one…?			
421.	S	Yes, next to…			
422.	R	Ja, next to it here. (i.e., ―Without the things that we get from Nature we could not enjoy the everyday life we have today" is pasted alongside ―I believe Nature needs to be protected" in the number one position.)			
423.	R	Is there anything else, um, you can think of that you want to say about what you think about Nature?			
424.	S	No.			
425.	R	Do you think we've, kind of, covered everything?			
426.	S	Yes, m'am.			
427.	R	Okay, and how have you found this? Has it been alright?			
428.	S	It was exciting, m'am.[27]			
429.	R	It was exciting! Oh, I'm so pleased! I must say I've really enjoyed it. Your examples have been so interesting, so good.			
430.	S	Ah, cool, thanks, m'am.			
431.	R	Thank you…(Before the student leaves, the interviewer gives the student an overview of what will happen in the coming few days.)			

[27] Personal response regarding his experience of the worldview interview

Appendix 3.17
CODES AND CODE DEFINITIONS EMPLOYED IN ANALYSING THE STUDENTS' INTERVIEW TRANSCRIPTS (i.e., WORLDVIEW INTERVIEWS & FOLLOW-UP INTERVIEWS)

Table A3.17-1: Code labels and definitions for epistemological descriptions—**Knowable**
(Definition: Nature is predictable and orderly. People can have significant material understanding of events in Nature.)

Code label	**Code definition**
Know (& Learn)	We know things about Nature. We can know such things about Nature. We want to know things about Nature. We need to know things about Nature. We can learn/discover abut Nature, find out things (e.g., school, books, television, computer/Internet) and figure out things about Nature. We use our knowledge about Nature.
Experiments	People test things in/with Nature to see what the results might be, and to prove things right or wrong. They take measurements, e.g., using instruments/equipment/machines. They use technology.
Observe[28]	We can observe things in/about Nature, and experience it ourselves. People go to that place in Nature, and they explore.
Understandable	We can understand things in/about Nature. It is not confusing or mysterious.
Explainable	We can explain things about Nature.
Predictable	We can predict things that will happen in Nature (e.g., warnings).
Simple	Nature is not complicated.
Not chaos	Nature is not chaotic.
Cycle	Things in Nature affect other things, which in turn affect other things. Things happen in a cycle (e.g., cycle of life).
Orderly	There is order in Nature (e.g., food chain). Everything has its place in this world. Everything links up.
Reason	Things happen for a reason. Everything has a purpose in Nature.
Controllable	We can prevent things from happening in Nature.
No change	Things don't change in Nature. Nature stays the same.

[28] See also *Physical* (Naturalistic)

Table A3.17-2: Code labels and definitions for epistemological descriptions—**Unknowable**

(Definition: Nature is so changeable and random that virtually nothing is predictable. The student is clearly more impressed with what is not known than what is.)

Code label	**Code definition**
Don't know	We don't know things about Nature. We cannot know such things about Nature. Some things we don't know for sure. Some things we don't need to know about Nature. Some things about Nature we should not know. [NOTE: In some cases, ―I'd like to know…" implies ―I don't know…]
Mysterious	Nature is mysterious and strange (weird)
Not understandable	We cannot understand things in/about Nature.
Unexplainable	We cannot explain things about Nature.
Confusing	Nature is confusing.
Complicated	Nature is complicated to understand.
Technology level	Our technology is not advanced enough to find out more.
Complex	Nature is made up of different stuff, and things are all mixed in the world. Different things happen.
Unknown	There is more to Nature. Some parts are as yet undiscovered (i.e., unseen, untouched).
Change	Things in Nature can change. Nature will change.
Unpredictable (& Unreliable)	We cannot predict things that will happen in Nature. It is unreliable.
Not orderly (Random)	There is no set pattern in Nature. It is not orderly. In Nature, things just happen. Things don't happened for a purpose/reason. Things grow wildly. There is lots happening at the same time.
Chaotic	Nature is chaotic. Nature causes chaos.
Not controlled	You cannot dictate to Nature what must happen. You cannot control what happens in Nature. People cannot prevent things from happening in Nature. Things happen when they want to happen. Nature is open and free. Nature runs itself.
Mistakes	We could make a mistake about Nature.

Table A3.17-3: Code labels and definitions for ontological descriptions—**Super-naturalistic**
(Definition: The student believes there to be supernatural involvement in Nature. The student refers to transcendent purpose, that is, a purpose beyond the level of the material structure/function in the natural world.)

Code label	**Code definition**
Spiritual	There is something to Nature beyond that which is physical (e.g., ghosts, spirits, the devil). There is a spiritual dimension to Nature (e.g., it calms you down). God is involved in Nature in some way. (e.g., God controls what happens in Nature.)
Created	Nature was created, but not by people. It was not just there. It is not man-made.
Holy	Nature is holy (e.g., pray to God).
Powerful	Nature is powerful, and Nature has its own power and energy.
Purpose transcendental	Things happen in Nature for a reason. They are supposed to happen. There is super natural involvement in things that happen in Nature (i.e., from a transcendental).
Nature as a being	Nature has its own personality.
Believe God	If Science and Religion tell us different things, I‘d rather believe God.
Other world	There was another world before/after this (e.g., Before-/After-life), including references to the Day of Judgment.
God knows	Only God knows what will happen.

Table A3.17-4: Code labels and definitions for ontological descriptions—**Naturalistic**
(Definition: The belief that material or physical causation provides a sufficient basis for understanding the natural world.)

Code label	**Code definition**
Not spiritual	Nature is not spiritual. I don‘t see the work of God in Nature.
Not holy	Nature is not holy.
Doubt religion	I‘m not sure I believe what it says in our religion.
Created by Nature	Things are created by Nature (as opposed to God having created things in Nature). It is things that are naturally there.
Nature runs itself	Nature does its own thing. It controls itself. Things happen when/how they want to happen.
Always there	Nature has been around for a long time. Nature was and will always be there. There is no beginning or end to Nature. It is just there.
On Earth	Nature is everywhere around us. You go out to Nature, it doesn‘t come to you.
Beyond Earth	Nature includes things that are in space.
Not blank	Nature is not blank. For example, there are animals, trees, and so forth.
Physical	Nature is solid. We can touch it and see it, and we can hear and smell Nature. Some things in Nature are tiny little organisms that you see under a microscope. Some physical parts can‘t be touched but it is because they are too far away or they are untouchable (e.g., too dangerous/too vast/not yet known).
Living	Nature is living. It is alive. It grows. Things in Nature move around.
Adapt	Things in Nature adapt in order to survive.
Belong in place[29]	Nature is things that belong in that place. They are supposed to be there. It is for naturalistic reasons that they are there.
Purpose physical	Things happen in Nature for a reason. They are supposed to happen (e.g., they are needed). The cause is physical/materialistic.
No function/purpose	Parts of Nature do not do anything. They don‘t have a job. Some things happen for no purpose in Nature. They just happen.
No brain	There are things in Nature that have no brain and no mind or heart of their own.
Not living	Nature is not living. It is not alive.
Not moving	Some parts of Nature do not move around.
Technology	There is more to Nature—it is technology (i.e., ―more” does not refer to supernatural elements).

[29] Different to *Orderly* (Knowable)

Table A3.17-5: Code labels and definitions for emotional descriptions: **Positive**
(Definition: Nature is something beyond the ordinary. The student has a positive emotional response to Nature.)

Code label	**Code definition**
Likeable	Nature is nice. I like it. I appreciate things in Nature. I enjoy being in Nature.[30]
Beautiful	Nature is pretty. It is beautiful. It looks nice.
Colourful	I enjoy all the colours in Nature.
Delicious	Nature is delicious. I like to eat things from Nature because they taste nice.
Peaceful	Nature is peaceful and calm.
Fun/Exciting	Nature is exciting. It is fun to spend time in Nature.
Amazing	Nature is amazing.
Unusual	Things in Nature are special, i.e., they are not everyday/ordinary. They are unusual. They are rare. It is a first.
Fascinating	Nature is fascinating. It is interesting to find out/learn things about it.
Think	I think about Nature.
Helpful	Nature impacts on man in a positive way. Nature helps and heals.
Good	Nature does not do things that are wrong.
Valuable	Nature has value. Some parts of Nature you pay for. They can be expensive to buy. Includes some reference to money or a purchasing transaction.

Table A3.17-6: Code labels and definitions for emotional descriptions: **Neutral**
(Definition: Nature is mundane and prosaic. The student has neither a positive nor a negative emotional response to Nature.)

Code label	**Code definition**
Just there	Nature is just there.
Ordinary	Nature is part of everyday life. e.g., Nature is used everyday.
Not dangerous	Nature is not dangerous.
Not frightening	Nature is not frightening. You don‘t need to be scared of Nature.
Don‘t think	I don‘t normally think that much about Nature.

[30] Some students used the word ―cool”, which is a colloquial term indicating approval and/or admiration (i.e., it can also mean ―nice”, ―enjoyable”, etc.).

Table A3.17-7: Code labels and definitions for emotional descriptions: **Negative**
(Definition: The student has a negative emotional response to Nature.)

Code label	Code definition
Boring	Nature is boring. Everything is the same.
Unappealing	Some parts of Nature are not beautiful or attractive to me. There are some parts of Nature that I do not like.
Not pure[31]	Nature is not pure. It is dirty.
Not peaceful	Nature is not peaceful.
Hurtful	Nature can be harmful. It can hurt man.
Nature kills	Things in Nature are killed Nature because of events from Nature. I feel sorry for the animals that are killed (e.g., by a lion).
Dangerous & Destroy	Nature is dangerous. It can destroy things (e.g., Fire burns a forest, volcanic lava destroys a city, etc.)
Frightening	Nature is frightening and it scares me.
Weird	There are unusual parts of Nature that are not considered positive or neutral.

Table A3.17-8: Code labels and definitions for status descriptions: **Resource**
(Definition: Nature is full of resources for mankind to use.)

Code label	Code definition
Useful[32]	Nature is useful and we use it. Things in Nature have a use. Nature is full of things we can use. Nature is there for us to use it.
Need it	People need things from Nature, in order to survive.
Reliable[33]	You can depend on Nature. It will just stand there. Nature will always be there.
Not over-used	Nature is not over-used. It is not used too much.
Not destroyed	Nature cannot be destroyed.
Not ruined	Nature is not doomed. It is not ruined. Things in Nature are not running out.
Can be restored	Nature can be restored. Sometimes Nature restores itself. Nature can repair itself.
Man's interaction	Man interacts with Nature (e.g., competition for space): it doesn't explicitly result in a positive or negative impact.
Man creates (Technology)	Some things are made by man. Technology reduces our dependence on Nature.
Mixture of different things[34]	Nature is made up of a mixture of different things (…that we interact with and use).

[31] Different to *Dirty* (Conservationist)
[32] Different to *Helpful* (Positive)
[33] Different to *Always there* (Naturalistic)
[34] Different to *Complex* (Unknowable)

Table A3.17-9: Code labels and definitions for status descriptions: **Conservationist**
(Definition: Nature is endangered and needs to be protected).

Code label	Code definition
Pure	Nature on its own is pure, and unspoilt.
Polluted	Nature is polluted by people.
Endangered	Nature is dying out. Some things in Nature are running out.
Extinct	Nature is extinct.
Over-used	Nature is used too much.
Cannot be repaired	If things in Nature are hurt they cannot be saved.
Man kills	Things in Nature are killed due to man‘s impact.
Man‘s impact negative	Things that people do to Nature that have a negative impact on Nature.
Conserve	We need to look after Nature. Nature needs to be protected. We can learn how to protect Nature.
Ruined	Nature is ruined.
Man‘s impact positive	People can/do things to help Nature.

Table A3.17-10: Summary of codes allocated to each bipolar descriptor pair

Worldview description	**Bipolar descriptor pair**	**Code labels**
Epistemological	Knowable	Know (& Learn) Experiments Observe Understandable Explainable Predictable Simple Not chaos Cycle Orderly Reason Controllable No change
Epistemological	Unknowable	Don't know Mysterious Not understandable Unexplainable Confusing Complicated Technology level Complex Unknown Change Unpredictable (& Unreliable) Not orderly (Random) Chaotic Not controlled Mistakes
Ontological	Super-naturalistic	Spiritual Created Holy Powerful Purpose transcendental Nature as a being Believe God Other world God knows

Table A3.17-10 (cont…)

Worldview description	**Bipolar descriptor pair**	**Code labels**
Ontological	Naturalistic	Not spiritual Not holy Doubt religion Created by Nature Nature runs itself Always there On Earth Beyond Earth Not blank Physical Living Adapt Belong in place Purpose physical No function/purpose No brain Not living Not moving Technology
Emotional	Positive	Likeable Beautiful Colourful Delicious Peaceful Fun/Exciting Amazing Unusual Fascinating Think Helpful Good Valuable
Emotional	Neutral	Just there Ordinary Not dangerous Not frightening Don‘t think
Emotional	Negative	Boring Unappealing Not pure Not peaceful Hurtful Nature kills Dangerous & Destroy Frightening Weird

Table A3.17-10 (cont…)

Worldview description	**Bipolar descriptor pair**	**Code labels**
Status	Resource-oriented	Useful Need it Reliable Not over-used Not destroyed Not ruined Can be restored Man‘s interaction Man creates (Technology) Mixture of different things
Status	Conservationist	Pure Polluted Endangered Extinct Over-used Cannot be repaired Man kills Man‘s impact negative Conserve Ruined Man‘s impact positive

Appendix 3.18
CONCEPT MAP CREATED FOR DYLLAN

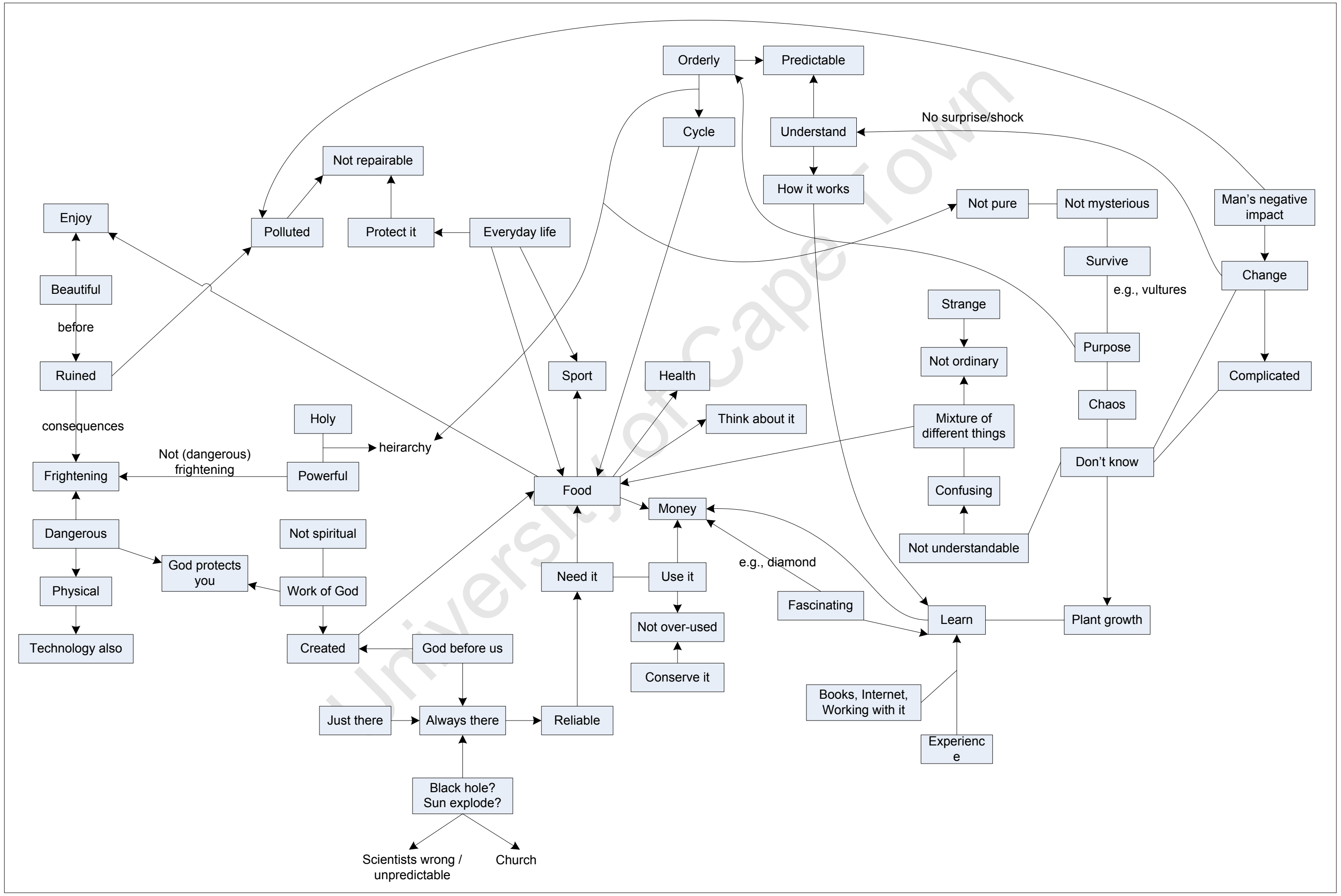


Figure A3.18-1: Concept map created for Dyllan

Appendix 3.19
WORLDVIEW NARRATIVE (‘NATURE STORY’) FOR DYLLAN

Nature is things that man didn‘t make. It has just been there all the time, like, before we were born. We can touch some parts of it only, like, the animals, cows and bananas, but not the whole thing at once. For example, we can‘t touch the lions because they‘ll eat us up, and we‘ll get sucked up if we try to touch a tornado. Most of Nature is not too dangerous to touch, but, like, the Amazon Jungle, it is too big for us to be able to see it and touch it all at once. And there is more to Nature than what we can see and touch, because, if you just see a tree as its full growth, we wouldn‘t know that it was this small and then grows and grows and grows, and that it needed water to get as big as it is at full growth. And there is also technology that we play with. We don‘t just play with Nature.

I think that there was no beginning to Nature, and it will always be there, like, the planets. We can die but the planets will still be alive. The earth can go into a hole but then there‘s still another five hundred million planets still there. Our teacher says in science that scientists say the sun is going to blow up or it is going to fall into itself, or the Earth is going through the same thing, but in one billion years. That‘s quite a long time. But I don‘t trust what they tell us, because when I go to church, they sing a hymn where the last line says, ―world without end” and it goes ―Amen”. So I think if God says there will be no end, I think that‘s right. I don‘t believe the scientists. They are not super-humans. They also make mistakes, so maybe they‘re wrong about the world ending.

We can rely on Nature. Apples, bananas, fruit, all come from Nature. We take bananas from the tree and we eat it, and we need it to stay strong and healthy. Honey from bees, that‘s also Nature. All food is created by Nature. We kill the cows, for milk for our porridge, and for meat, also chickens, and the fire we use to cook our braais,[35] which is the meat. So we need Nature. We need food to survive and food only comes from animals and plants. We also use the diamond. We sell the diamonds to get money so we can eat more food to stay healthy and carry on living. We make paper from trees for the factory to make money. We give the paper to schools and stuff like that. But I think that they should cut up only a small part of a jungle each month, not the whole jungle at once, because if they cut down a tree, we can‘t sew it on again. It will just be off and that‘s the end of it. But the tree that gives us bananas, if it‘s been watered often then it will stay alive and give us more bananas. Then we won‘t be using too much of Nature.

In Nature, we can tell what‘s going to happen in the future, for example, people say that in 2012 there‘ll be another eclipse where Venus will come over the sun. They say the next time that will happen is, like, in the thousands of years‘ time, so there must be some order in Nature. There is, like, a cycle in Nature. For example, the cows eat lots of grass, then their tummies get big then they can give us milk. Then we drink the milk to stay healthy so we can still feed them. We can understand Nature if we learn about certain parts of it. For example, my old science teacher, Mr. [G], used to talk about fynbos[36] and that it needs fire to survive. So it has seeds in its leaves and when it burns it goes to the ground and then it makes more fynbos. That‘s why we have science—to learn more about Nature so then there‘s more stuff we know about it. But if I haven‘t learnt about something then it would be confusing. It is interesting to find out facts about Nature, like, with the diamond, I didn‘t know that the Earth moves and that‘s how we get diamonds, but it doesn‘t happen often. That‘s fascinating for me. We can find out things about Nature from the Internet, and books, and we can experience it ourselves, for example, by going to the jungle or somewhere. Or maybe people experienced a volcano erupting, or they are an archeologist that found fossils. Maybe they are farmers, and they collect honey so they know where honey comes from, or they farm with cows and see how they make the milk. What I would still like to find out is, how do plants grow? What‘s in the plants that makes them shoot out? And sometimes I wonder, with my dog, he just does this weird stuff and there‘s no real answer. Sometimes he just digs holes in the ground even if he has no bone. I don‘t understand that (111). And he‘s got an ear problem, so we keep cleaning out his ear and we take him to the doctor and then his ear is fine again, but afterwards his ear is funny again. It goes on like that forever, so it‘s confusing to me. There is some stuff in Nature that we can‘t give

[35] Barbecues
[36] Indigenous vegetation in South Africa

an explanation for. And Nature is also confusing because, for example, the cow and the vulture are the same size but the cow doesn‘t go near killing things, so they do completely different things. Things in Nature have completely different styles of living, so it‘s quite strange. There are things that happen in Nature that‘s quite strange, like, the desert. How did all that sand get there? It‘s not simple and ordinary, like, you see a whole place full of sand and it‘s quite strange to see. And when I look at a jellyfish, I just see this thing, and it looks quite strange, and all the animals look quite strange because they all play different parts in their lives. Every animal has a different role, like the bee gets honey from a flower and he puts it in the hive. A cow eats and then he gives us milk. Also, with the lion, she goes and hunts for food and then she brings it back to the house where the cubs are, and then feeds it to the little lions so they can survive and hunt for themselves. Vultures eat all the meat off an animal and then the hyenas come and they eat the bones. Then everybody‘s surviving. Animals eat each other to survive and that‘s the way they live. We get used to it and so it‘s not mysterious for me. But when the lion just kills another thing for no reason, so he can be on the top, king of the jungle, then that‘s not pure. That is cruel.

Nature is complicated. Volcanoes just erupt. Why do they erupt, if for five years it stays the same and then it just blows up all of a sudden? Why do hurricanes start? How do they start? Why do fires happen and just grow and grow, and cause havoc? So Nature changes, like, volcanoes. Some of the time, changes that happen in Nature are caused by people. Like, if they cut down all the trees, then there‘s less trees and then the birds can‘t live in the trees and so that changes. Then where would their nests be built? And if the nest is on the ground then other animals eat the eggs and then there are no more birds. Those are bad changes.

We need Nature for our everyday life so I am worried about the pollution. If I think about soccer and cricket, you need grass to play those sports. Because if there was just sand it wouldn‘t be such an easy game. They cut trees down and then the banana‘s tree won‘t grow any more and give us more bananas. And if we didn‘t have a banana in our life then we wouldn‘t have so much energy and we won‘t be as fit and strong, so then we wouldn‘t be able to run around and play soccer, and cricket, and rugby. If a dog dies, you can‘t put him back to life. So Nature cannot be repaired.

I enjoy Nature. I love eating fruit, I like mangoes. And I like experiencing Nature. For example, going to the jungle and seeing an elephant walk past the car, or hearing a lion roar. If I see it on TV[37] it is amazing but it will be amazing for me if I‘m there, like, maybe a couple of feet in front of it. Or to see a volcano erupt—but I would get out that place! Nature is beautiful, for example, when I take pictures in the Kruger National Park. But if you chop down all the beautiful trees, like, maybe a million trees from one forest, and we go back to the forest, look at it and see, ―What have I done? There‘s no more trees. This is just a whole lot of sand. I‘ve ruined that part of land". Then it is frightening.

Nature is powerful, like, the fire and the volcano. We can‘t stop that. I‘d also be scared to be in America and experience a tornado or a hurricane and see my house blow up. So some of Nature is dangerous. I‘ll get scared of animals like lions that are bigger than us and will eat me up, but we can stop a lion from eating us, by injecting them with stuff to drug them and putting them in a cage. And when a bee stings us, he dies but we don‘t come close to death. Also, my ma normally tells me everyday—and I believe my ma—she says that if you pray a lot and you thank God for your food and you don‘t just take it, then if a lion came to your house one day, God will put the barrier around you and the lion won‘t interfere with you. I see Nature as the work of God. But it is not spiritual in the sense of people sacrificing cows, playing drums and singing songs. It is holy in the way that animals like vultures look up to the lions and they don‘t attack them. It‘s, like, who is number one in the jungle and controlling.

[37] Television

Appendix 4.1

RANGE OF NOS VIEWS DESCRIBED BY THE STUDENTS, PERTAINING TO VARIOUS LEVELS OF UNDERSTANDING ABOUT EACH OF THE FIVE TARGET ASPECTS OF NOS

Table A4.1-1 : Range of **informed** views regarding the **empirically-based** aspect of NOS

Theme	Sub-categories of themes	Theme definition	Illustrative responses from the students
FACTUAL KNOWLEDGE	FACTS & TRUTH	Science is based on factual knowledge. Scientists search for the truth.	“They gather information and put together what they need…Gather information: investigate and find out more **facts** about what they are looking for.” (Maya) “Most of it is [based on facts]. When you find different things (facts) you have to make facts about them to let the world know.” (Victoria) “Scientists need to find the **truth**, not the imagination in their heads.” (Shanon)
	INFERENCE: BASED ON FACT	Scientists make inferences based on the facts.	“[What scientists think is also part of science] because sometimes they have to use their imagination, like for pictures and artifacts, they need to find out, they have to use their imagination a bit. I think I said about the pots and stuff…**they find out facts and then they use their imagination to build up about the thing** that they‘re trying to, like what it looks like (i.e., If it looks like a piece of clay it must have been pottery).” (Maya) “[Scientists can start with whatever they‘re not sure about and then they come up with pictures] because **they’ve first got the bones and then they put it together** and then they scan it, like, on the computer. And then they got…the eyes and stuff, and then they made that, the dinosaur…And then they put the skin on and the colour…maybe it‘s just according to what they eat or where they used to live…they can become sure [of that]…by the time they‘ve come up with a picture that they tell us, it‘s…facts].” (Aaeesha)
	CHECK	Scientists check their work to avoid publicizing erroneous information.	“…I‘m sure that a lot of scientists make mistakes all the time but then they don‘t go, they‘re not…scientists, they like <u>triple check</u>, they go over and over again just to make sure it‘s perfect, so if they do make mistakes, then hopefully they‘re gone over again and then they‘ll correct it before it gets out to us…” (Shanon)

Table A4.1-1 (cont…)

Theme	Sub-categories of themes	Theme definition	Illustrative responses from the students
FACTUAL KNOWLEDGE	BOOKS	Scientists can get their knowledge from books.	―[Scientists get their knowledge from] **books**...” (Aamir)
			―...Research means looking for something to me…Like I might be researching a country…I might be researching a person…You would either **go to** the country, also the people who live there, ask them their old cultures, go to the museums, **look in their libraries**, that‘s how you‘d find it.” (Shafia)
ARCHAEO-LOGICAL EVIDENCE	BONES, TEETH, AND FOSSILS	Scientists dig to find bones, teeth, and fossils.	―Archaeologists look for **remains of dead dinosaurs** under the surface…”(Brian)
			―e.g., The **fossils**, where they used to live and what used to be around where they lived and if they found the face [**skull bone**] they see how the **teeth** were and things.” (Aaeesha)
			―They can tell by the structure of their **bones** how they looked like and they can tell what they ate by looking at the size and shape of their **teeth**. e.g. Molars, incisors, canines, etc. and sharpness...e.g., carnivores had long canines.” (Raashid)
	SOIL SAMPLES	Scientists examine soil samples.	―From their bone structure and their teeth…and also from the **soil** around the bones because most of the nutrients are still in the soil around them.” (Victoria)
STUDY, OBSERVE, GO THERE, SEARCH	STUDY	Scientists study various things in Nature.	―Scientists **study** and research things, for example, plants, animals, people. They search for the thing and **study** it: (i) find the certain thing they‘re looking for; (ii) **study** it, take photos of it, watch its life, see what they‘re like; If they‘re **studying** people, they‘ll ask them.” (Shafia)
			―[If a scientist‘s **studying** a plant or an animal, it is] because they look for cures to sicknesses, they look for if it‘s poisonous stuff, ‗cos if people go out in the jungle, for...a holiday, and then they come across [something]...Oh, it looks so cute, picks it up…it could be poisonous.” (Shafia)

Table A4.1-1 (cont…)

Theme	**Sub-categories of themes**	**Theme definition**	**Illustrative responses from the students**
STUDY, OBSERVE, GO THERE, SEARCH	GO THERE & MOBILE LAB	Scientists go to the place they are studying, to find what they are looking for. They have mobile laboratories.	―[Scientists do their work] in a laboratory or anywhere where they can work/research… Some they might…work in, of what they‗re studying, they want to know stuff about mountains, and…about the earth, the natural earth and that, then they might…have…a wandering place [a mobile laboratory] where they work and they work wherever the mountain is…[and the people who research the ocean] they see where different animals stay in the ocean…" (Samuel) ―When I talk about research, is when you **go out** and you look for something…A plant, you would **go to the place** where you find that plant..." (Shafia)
	SEARCH	Scientists search to find evidence of the things they are studying.	―Ja. And they must show the people. They can‗t just say, ―Ja, I found it." They must show how hard work they done. Because the other people think so, no, scientists just so…**they must see how hard the scientists go and search**. Can‗t say scientists just done that and that. **Because to find out there is a lot of work** […] It takes like more than a lot of years to go. You will be interested in there but it is a lot of years to go and find out everything. Because this piece here, say now here‗s the whole world here, this quarter piece[38] here only **you take [a] whole lot of years…ten fifteen years more than *seker*[39] that to go find out, to get everything right, to clear it, tidy the spot, clearly know about it, clearly search, a lot of time…**Because there are some scientists you can get, ja, we got it, ja, on this paper what they see they take everything. But if you take…that piece out of there, there‗s more things there hidden there. **You have to search a lot, you can't just see, this, this, this, write it down. You have to open it**, like, here‗s a moon […] I know a moon won‗t move, I‗m just saying, you can move the moon you see here‗s more things you can write that down…[there are always more things] never less." (Reza)[40]

[38] What he indicated by means of hand movements seemed closer to one sixteenth.
[39] Afrikaans work meaning, ‗for sure‗.
[40] Paraphrased: Scientists work hard and have to search everything, not only describing what they see in a small area or on the surface, but also searching in-depth—there is a great amount to find out about the world.

Table A4.1-1 (cont…)

Theme	Sub-categories of themes	Theme definition	Illustrative responses from the students
STUDY, OBSERVE, GO THERE, SEARCH	SEARCH	Scientists search to find evidence of the things they are studying.	“[Scientists do their work] in their offices…or they search…**Go to different places and search** what did they do (e.g., Khoikhoi/San)…Mountains and all this…pretty flowers and all that…That‘s are facts…One searches a bit and another searches the whole way. The one who searches a bit might be wrong. **The one who searches the whole way is right**.” (Reza)
	OBSERVE	Scientists look at things in Nature.	“...**there are different things in the world that scientists can look at**.” (Aamir) “They research stuff that has been discovered or investigate it…They can **look at** rocks or mountains and work out stuff…” (Samuel) “**They can see by the sky…They look at the clouds** to see if it will rain the next day…” (Dan)
	TELESCOPE	Scientists look through telescopes to see things.	“To see if there are other planets, they look through a large **telescope**” (Brian). “They study all kinds of things…e.g., ...stars in space...[they use a] **telescope**...” (Maya)
	ANALYSE	They look closely at the phenomenon they are studying.	“[Scientists] **look closer** (analyse) the item/term and figure out clues that‘ll give answers, then go deeper to figure out details.” (Shanon)
	DISSECT	They will break it apart and look inside the thing they are studying.	“[When they study fossils] maybe they will **break it open** and look at it and feel the different textures…[in the lab].” (Yamina) “They study all kinds of things…e.g., plants, bodies, animals, stars in space...e.g., **Bodies: go to a hospital and look inside the bodies**...” (Maya)
RESEARCH, INVESTIGATION, & EXPERIMENT-ATION	RESEARCH	Scientists do research.	“They **research** stuff that has been discovered or investigate it…Some might **research** the ocean.” (Samuel) “When I talk about **research**, is when you go out and you look for something. **Research** means looking for something to me…Like I might be **researching** a country…I might be **researching** a person, I might be **researching** a plant, animal. **Researching** is finding out things about that thing…” (Shafia)

Table A4.1-1 (cont…)

Theme	Sub-categories of themes	Theme definition	Illustrative responses from the students
RESEARCH, INVESTIGATION, & EXPERIMENT-ATION	ASK PEOPLE	They ask people in order to find out more.	“Scientists study and research things, for example, plants, animals, people…If they‘re studying people, they‘ll **ask them**.” (Shafia) “…I might be researching a person...You would either go to the country, **also the people who live there, ask them** [about] their old cultures...” (Shafia)
	INVESTIGATE	Scientists investigate things.	“They research stuff that has been discovered or **investigate** it…They can use DNA to **investigate**…” (Samuel) “They gather information and put together what they need…Gather information: **investigate** and find out more facts about what they are looking for.” (Maya) “Some are a little bit unsure [about their knowledge of dinosaurs], some of them are certain. They are only certain when they have finished **investigating** and looking at what they need.” (Maya)
	EXPERIMENT	Scientists do experiments.	“Once you have done **experiments** and have confirmed what you thought were myths become facts” (Gideon). [Re: **experiments**] “I saw it on TV—they mix them to see what‘s the reaction.” (Brian) “Every **experiment** has a different way of proving it. Some need the whole lab with every last bit of equipment and others are just simple experiments.” (Gideon)
	CHEMICALS & LAB	Scientists work with chemicals in a science laboratory.	“Scientists do their work in a lab with chemicals that help them know more about what they are dealing with.” (Dyllan) “[Scientists do their work] in a **laboratory** or anywhere where they can work/research…In a laboratory, like, with the long things, of putting the purple stuff in the blue stuff, if goes *pfff* [41]… That‘s what I imagine scientists. But that‘s only a few scientists…” (Samuel)

[41] He mimics the sound of a soft explosion.

Table A4.1-1 (cont…)

Theme	Sub-categories of themes	Theme definition	Illustrative responses from the students
RESEARCH, INVESTIGATION, & EXPERIMENT-ATION	TESTS	Scientists do tests.	—They take the problem and find ways to solve them, and they **test** their theories.” (Victoria) [Re: finding out they‘ve made a mistake] —He won‘t figure it out after he‘s done a **test**. (i.e., not immediately afterwards.) Like, a day after he done a test. Like a day after he will figure it out. He might check on it again…Maybe it turns a different colour or something also.” (Aamir) —People sometimes think they found an alien in their house then scientists do **tests** on it to tell that person if it is an alien or not.” (Dyllan)
	PROVE IT	Scientists work with facts that have been proven.	—They have to work with **facts that have proven to be true**.” (Samuel) —First you look at what you have at the facts, then once you have done that you do experiments to help **prove** your answer” (Gideon). —Every experiment has a different way of **proving** it...” (Gideon)
USING TECHNOLOGY	MACHINES AND COMPUTERS	Scientists use machines and computers, e.g., they scan things on the machine/computer and it tells them.	—He‘ll go through a different process, for fingerprints *(vs. blood tests, germs, etc)*. He has to get the fingerprints first off the car. And then he has to put it on the **machine**. Then you need the **computer** to print...the scannings on…” (Aamir) —To find out about skin colour they **scan it into a machine** and it tells them.” (Yamina)[42] —Ad use maybe a satellite…I don‘t work with **computers**. They might have a different programme for the **computer** where they can run it through to the satellite. So the satellite can tell them everything that happened…they use technology, so, technology most of the time is never wrong, so you can trust the technology that they use.” (Aamir) —They use a **machine** to discover what the weather will be…It has the temperature in a box and then they‘ll open the box to see what the temperature will be.” (Yamina)

[42] When analysing the students‘ levels of NOS understanding, the focus was on how the students‘ reasoning was constructed in regard to particular aspect/s of NOS, as opposed to the scientific accuracy of what the student said. This analytic approach was validated by an experienced researcher of NOS.

Table A4.1-1 (cont…)

Theme	Sub-categories of themes	Theme definition	Illustrative responses from the students
USING TECHNOLOGY	SATELLITES & PICTURES	Scientists use satellites and they take pictures of Earth and Space.	―The **satellites in space take pictures of earth** so scientists have an idea of what the weather will be like for the next few days.” (Brian) ―They sent **pictures**, they sent...a Voyager out to space and...that took **pictures of space**, so that would give them idea of what it was like.” (Dyllan)
	MEASURE	Scientists use tools and instruments to take measurements.	―They use aeroplanes and machines and the wind…Before machines they predicted the weather with a thing made of wood. It turns something on top and an arrow goes to cold weather or hot, so they see if it will snow, etc.” (Shafia) ―They use tools to **measure** what time certain weather will hit us—in different places in the world.” (Shanon) ―They test the temperature and see which way the wind is blowing and what wind it is…” (Aaeesha)
MORE THAN FACTS	DISCOVER	Science is more than facts: it is also things that are discovered.	―[Science is not only based on facts because] there are also inventions and **discoveries** from scientists...e.g., **New planets**, inventions, cures for illnesses. These are different to facts because facts just tell us about the object or something. **Discoveries are something that no-one else knows about**...” (Brian) ―[Scientists get their knowledge from] books…[and things that they‘ve **discovered**]…Most of the time it‘s things that they‘ve discovered.” (Aamir)
	INVENT	Science is more than facts: it is also inventions.	―[Science is not only based on facts because] there are also **inventions** and discoveries from scientists...e.g., New planets, **inventions**, cures for illnesses. These are different to facts because facts just tell us about the object or something...**Inventions are things you create**” (Brian). ―[Scientists] **invent** things, work with chemicals, study Nature, find cures to things.” (Victoria)

Table A4.1-2: Range of **developing** views regarding the **empirically-based** aspect of NOS

Theme	Theme definition	Illustrative responses from the students
ANYTHING	Science can be based on almost anything.	“It can be based on a belief, a term (i.e., a theory), an object (e.g., tree), a human (i.e., us!)—**almost anything**”…[A term/theory is something that you‘re trying to prove yes, it‘s right or no, it‘s wrong]. (Shanon)
HOW EXACTLY?	Although there are some references to scientists searching and investigating, it is unclear exactly how scientists develop their knowledge.	“…the weather…they will go and find out about the weather…They go up…into the sky…and they go see about the weathers…**I don’t know how** they know how this weather comes. But I know the facts they based on weather all that…But I want to know that for real. How do they get to know tomorrow‘s raining? How do they tell us on television…I want to know.” (Reza) [Scientists know about dinosaurs] “because of the jaw and the sharp things at the top of the head.” (Reza)[43]
DOUBT IN SCIENCE	Scientists found evidence, but I‘m not certain of what they tell us.	“They found fossils buried in the earth and bones had certain nutrients in them. I don‘t even know if I believe in dinosaurs—it‘s so long ago and it doesn‘t make an impact on our lives now… **They are certain, I am not**.” (Shanon)

[43] There is no clear indication of *how* scientists know this, however, the student‘s statement reveals an emergent understanding about scientists having found jaw bones and evidence of spikes.

Table A4.1-3: Range of **naive** views regarding the **empirically-based** aspect of NOS

Theme	Theme definition	Illustrative responses from the students
MIS-INFORMATION	Scientists tell us the wrong thing.	“Because sometimes scientists haven‘t done something and **then they can give you the wrong advice**…e.g., Invent an electrical fence: They might tell you what to use to make it before they‘ve checked it is right and it‘s actually wrong.” (Dan) “It could be like…if they could miss a fact and **they could get something wrong** and then if they go and sell the wrong idea to a big company that spreads it all over the world, and then suddenly you get people getting sick and stuff… Sometimes they can make an innocent mistake, and sometimes they can just be bad people, but hope not!” (Shanon) “…Scientists haven‘t been up close to Saturn and, you know the Voyager 2 or 1, I think it was the first one they sent out, that‘s only passing Pluto now…Maybe it‘s a long time past Pluto. That‘s another thing, M‘am…That‘s what Mr. [B] says, M‘am. Voyager 1 that was sent out so they can experience our solar system, Mr. [B] says it‘s only gone passed Pluto now…And that it‘s shut down because it works off solar power and now it‘s not getting any sun because it‘s past Pluto. So, **maybe it's not** past Pluto. I don‘t know, M‘am. It‘s strange. Or maybe, as they passed Pluto another sun came so it was still on…it‘s quite confusing!” (Dyllan)
DISHONEST	Scientists could be corrupt businessmen or they could try to kill you. Perhaps they are tricking us or trying to fool us. Or they might be concerned about personal fame.	[Re: Can we trust what scientists tell us?] “Sometimes: We don‘t know what goes on in their labs…We don‘t know what they use. e.g. Their cure for AIDS could just be water….Are they **corrupt businessmen** or truly good people trying to improve our lives?” (Shanon) [Re: Where do scientists get their information from?] “It‘s pretty strange…because, like… Mr. [B] had this book. And it showed us of, a picture of the sun, up close, but wouldn‘t that Voyager 1 burn if it was up close, you know? Or…they took a picture of the Milky Way galaxy how it looks in space. But the Voyager 1 only passed Pluto now! And that‘s the first one that we sent out, so…**maybe they're tricking us**.” (Dyllan) “Achaeologists found bones...fossils of the dinosaurs, but obviously the skin has been eaten up by—and then, all they find is the bone, and they brush it and that, and all they see is the bone. But **what if they are fooling us** by just putting on skins but with the shape of the dinosaur‘s body and then they find another one and just put- just make his skin colour green. But if you go back in time it‘s red…?” (Dyllan) [Re: Do you think that if all scientists have the facts they‘re going to come up with the same answers?] “No, I think they will just make excuses to say that they are wrong, like, mmm, I don‘t know, I can‘t think of an [example of an] excuse. [It is just so that they can find out for themselves…**so that they can be the ones to have the…] glory or something**.” (Brian)

Table A4.1-3 (cont…)

Theme	Theme definition	Illustrative responses from the students
DON‘T NEED FACTS	You don‘t need facts to do science.	―Science is electricity and fluids so **you don’t need facts to do science**...There are some facts with electricity but it‘s mostly using it or making something.” (Dan)
I DON‘T KNOW	I don‘t know how scientists know what they tell us.	―**I don’t know**…It is based on what they tell us.” (Dyllan) ―**I don’t know how they knew** [about dinosaurs]…Nobody really lived back then.” (Dyllan) ―**I’m not too sure** [how scientists go about their work] because I‘ve seen a lot of movies and they say, ―We must go our lab,” and then they have chemicals and technology and stuff, and then I think they just do that. But **I’m not too sure** if they also, ‗cos I know space is Nature because it always was there, but they don‘t really study, they don‘t work with that, because they can‘t touch the planets, do you know what I mean?” (Dyllan)

Table A4.1-4: Range of **informed** views regarding the **theory-laden** aspect of NOS

Theme	**Sub-categories of themes**	**Theme definition**	**Illustrative responses from the students**
THOUGHTS & OPINIONS	n/a	Scientists have different beliefs and ways of thinking, and they use their opinions. Sometimes they picture things in their heads.	“Some of the scientists **believe** different facts and that then makes them **theories**.” (Victoria) “They don‘t know for sure but what they found so for the picture indicated is what they **think** dinosaurs look like.” (Aaeesha) “I think that…most of the time, their own **opinions** are [involved]. Yes, because you have to add your opinions to make more sense of it, otherwise it will just be a whole lot of facts…That‘s why they‘re sometimes a little bit unsure, because…scientists have their own opinions, their **different opinions**. That‘s why they‘re a little **unsure**, ja.” (Victoria)
LACK EVIDENCE	Lack information	There is no hard evidence and scientists don‘t have enough information about it.	“There is **no hard evidence** of how the dinosaurs died.” (Victoria) “Sometimes they have a few facts and it‘s sometimes right. But we can‘t always be sure. If they are wrong it is because they **don’t have enough information**.” (Shafia)
	Not there	Sometimes the evidence is no longer there for scientists to look at, or scientists weren‘t there at the time.	“I have heard people say that there was no food so the dinosaurs died. And I heard a volcano killed the dinosaurs. But no-one was alive then so it was difficult to give a right answer; It is very difficult to say how scientists know how dinosaurs look like because **they weren’t there**.” (Dyllan) “e.g., Dinosaurs—muscles around the bone, and skin. **The dinosaur isn’t actually there for them to look at**...**They haven’t seen them for themselves**.” (Victoria)
UNCERTAIN	n/a	Sometimes scientists are unsure of what they tell us; Sometimes we‘re unsure of what scientists tell us—what they tell us *might* have happened.	[Re: dinosaurs] “…We trust [scientists], but we‘re not sure. The more facts they have, the more we trust them. At the moment, we‘re not sure.” (Shafia) “For example, if you find a picture on a rock about a ancient time **you wouldn’t know for a fact** who done the picture.” (Raashid) “The truth is the truth. And facts are **what could have happened** while the creature was alive…” (Yamina)

Table A4.1-4 (cont…)

Theme	Sub-categories of themes	Theme definition	Illustrative responses from the students
EVIDENCE-BASED	Guess & estimate	Sometimes scientists guess or estimate to fit in with their facts.	—If they find a dinosaur fossil but then they don‘t find one bone, they **guess** what it might look like…If you‘ve got a full skeleton and…you can see that one of their fingers are missing and you‘re looked around that square kilometre or whatever and you can‘t find it there, then they might just **estimate** or make up that bone just to complete it.” (Samuel)
			—Scientists **guess** sometimes to fit in with their facts…—I‘d say 90% is based on facts and the other 10% or whatever is…estimating.” (Samuel)
	Consistent with evidence	The ideas that scientists tell us come from the evidence that they have.	—They picture what the creature or thing looked like...If they don‘t know what the creature looked like they‘ll listen to the name and try to picture what it looked like. **They use different animals that have a similar sounding name**. Then they‘ll use a part of that animal [and apply it] to the animal that they are studying…” (Yamina)
			—Facts are things they‘ve thought of so they come from people. Truth is what it is really. Science is more based on truth but there are facts involved...They come to their facts because **they see it in their work**. Then as they‘re studying that thing they see something else—they add that piece of knowledge to the rest of the truth. Then it becomes part of the truth.” (Yamina)
	Plausible & Makes sense	What scientists tell us must be plausible, and we believe the scientists that make the most sense.	—**You believe the one who makes the most sense to you**; I trust the things that scientists tell us because most of the time what they say actually makes sense...You can understand what they say...So [I‘m] going to listen to the facts and [I‘m] going to think, ‗Ja, that sounds reasonable, that must be true‘.” (Victoria)
			—…[But] *those* stories are [not] real science.] Because they‘re not thinking about it. How can the sun just float around and just miss Earth or something?...Like, when I said that the sun...comes to heat Earth and then Earth just moves, and then why would it, why could Earth just move around and the sun just misses? [So [it] is because **the idea that they're coming up with…doesn't sound like it's gonna be] true**.” (Brian)

Table A4.1-4 (cont…)

Theme	Sub-categories of themes	Theme definition	Illustrative responses from the students
EVIDENCE-BASED	Test & Prove	Scientists test their theories to prove if they are right or wrong.	―It can be based on a belief, a term…Term [means] a theory…[**something that you're trying to prove yes, it's right or no, it's wrong**]" (Shanon). ―They take the problem and find ways to solve them, and they **test their theories**." (Victoria)

Table A4.1-5: Range of **developing** views regarding the **theory-laden** aspect of NOS

Theme	Theme definition	Illustrative responses from the students
FACTS & OPINIONS	Science involves facts and opinions, although opinions don't have the same status as facts.	―**Fact** = e.g., Once dinosaurs walked on the Earth [i.e., telling what happened in the past]; **Opinion** = the biggest dinosaur to walk on Earth was Tyrannosaurus Rex...[Re: T-Rex is the biggest is an opinion] Because you **think** that it's the largest, and you don't **know** that it's the largest. [It would be something you know] if you looked it up on the Internet and then it said ―**facts** about dinosaurs" and then it said the-. (Dan)
ALMOST CORRECT	What scientists tell us is almost correct.	[Re: Can scientists actually tell what dinosaurs looked like?] ―**It won't be the exact same picture, like that, it will be** close." (Aamir)
NOT 100% SURE	Scientists aren't 100% sure about it.	[Re: Can scientists tell us what the weather will be like?] ―No most of the time. I remember once on the weather they said it's going to be cold. So this lady went to go put on a lot of clothes. So she got heat stroke and she sued the weather company." (Aamir)
ALSO INVENTIONS	Science involves more than facts—it is also inventions.	―Science is electricity and fluids so you don't need facts to do science...There are some facts with electricity but it's mostly **using it or making something**." (Dan) ―Opinions are part of science because they are **part of an invention** which could be successful (e.g., a car that's now on the road) or it could fail**.**" (Dan)

Table A4.1-6: Range of **naive** views regarding the **theory-laden** aspect of NOS

Theme	Sub-categories of themes	Theme definition	Illustrative responses from the students
FACTS	ONLY FACTS	Scientists tell us the facts.	―[Science is only based on facts] because **you have to find facts** about what you are studying and then you can look even further...for more facts.” (Maya) ―[Science is only based on facts.]” (Gideon) ―[Scientists get their knowledge from] **books**…[and things that they‘ve discovered]…Most of the time it‘s things that they‘ve **discovered**.” (Aamir) ―Well, they **have to find out more and more** until…[they are sure about it…so that it can be **facts**.” (Aaeesha)
	TRUTH	Scientists tell us the truth.	―Some scientists find the truth about Nature.” (Yamina) ―[Some people disagree that humans were once apes]. I really don‘t know [why]. Maybe some people just don‘t believe that…apes could turn into humans…Then they should just say that they‘re not sure because **they can’t tell people things that’s not true**.” (Gideon)
	FIND EVIDENCE	Scientists first need to gather all the facts.	―[Scientists sometimes disagree] Because they are not very sure…They don‘t know everything…One searches a bit and another searches the whole way. The one who searches a bit might be wrong. **The one who searches the whole way is right**…Sometimes half a way they search so they don‘t know everything. They won‘t tell until they know everything. They will eventually find out everything so they can tell people.” (Reza) ―**They won’t put extra things in there**…Not [things that they have] thought, **they have to look**, They can‘t just…because then the other people would go focus on there they would say, ‗No, he‘s talking the right...that‘s [a] lie, they‘re talking lies about it…‘ ” (Reza)

Table A4.1-6 (cont…)

Theme	Sub-categories of themes	Theme definition	Illustrative responses from the students
FACTS	USE TECHNOLOGY	Scientists get the facts by using technology.	―[Re: Why I believe scientists] They use technology, so, **technology most of the time is never wrong**, so you can trust the technology that they use.” (Aamir)
			―They can use a computer to look back in time...I don‘t know [how they do that because] I don‘t work with computers. They might have a different programme for the computer where they can run it through to the satellite. So the satellite...can tell them everything that happened...” [44] (Aamir)
CONFIRM & PROVE	n/a	Scientists first check what they tell us, to confirm it is correct, and to be able to prove it.	―Once you have done **experiments** and have **confirmed** what you thought were myths become **facts**...Examples of myths: They thought it was impossible to go to the moon. Now it‘s a fact—it‘s happened…e.g., Nine planets: now it‘s been proved wrong. Now there are ten.” (Gideon)
			―For a very long time people have been talking about going to the moon, and it happened about twenty years ago, it happened about three years ago. So, I mean, the question is, was it or was it not a…myth before it happened? [And they say it‘s not possible now to live in space permanently but in the future it might be…] Is it a fact, or is it just a story…? [And with evolution, it is possible to evolve more still, but it‘s in the future and we don‘t know what‘s going to happen in the future…[That is not part of science] because I think that even if they tell us stuff now, I think there‘s a very good chance of it being different in the future… Myths aren‘t part of science—**only when they've been confirmed**.” (Gideon)
			―...You can‘t just take guesses and use your imagination. **You need proof** (e.g., what people looked like [in history]. (e.g., not when they do investigations).” (Raashid)
NO GUESSES	n/a	Science does not involve scientists guessing or their own thoughts.	―They might also find different facts and may guess a bit but that might not lead to the correct answer or what they‘re trying to find. **So it would be better to go and find out, more easier than guessing** because then it might lead to a different answer and it might [not] be true…” (Maya)

[44] The student does not acknowledge the role of subjectivity or theories in the development of scientific knowledge.

Table A4.1-6 (cont…)

Theme	Sub-categories of themes	Theme definition	Illustrative responses from the students
NO GUESSES	n/a	Science does not involve scientists guessing or their own thoughts.	―[Guessing is] kind of similar [to when they use their imaginations to work out stuff]. They use their imaginations…because they might have two options and they go, okay, which one could it be? [So it is working it out from the fact. But **a guess is not really as based on the facts**. So...[**the guessing wouldn't** be part of science] **because then it's not actually going out further, they're just guessing**. [When they guess they‘re basing it on] whatever they are trying to find, like they could just say dinosaurs were pink, but even though they might not have been pink]." (Maya)
UNSURE UNTIL FACTS	n/a	Sometimes scientists don‘t know everything and they are unsure, until they have enough facts and then they can tell people.	―Because some stuff today they are accurate and there are facts and lots of other stuff...[Other stuff refers to] stuff they‘re not sure about yet and they find out more about it at the moment. **Then they'll become facts when they are sure about it**…[Other stuff is also]… things they know, **but they're not sure about it, so they're not telling other people**. They just want to find out more about it first… **Some of it can become facts**. Um…Actually, **they can become facts if they're sure about it**…" (Aaeesha)
I DON‘T BELIEVE	n/a	Scientists don‘t tell us the truth, and I don‘t believe what they say.	―Scientists say that the space comes to an end. **I really don't believe.** I think it goes on forever…" (Dyllan) [Re: Is what science tells you the absolute truth?] ―Mhm, no. M‘am…why I say no, m‘am, is because Mr. [B] says if I go out to space…swim in space…it‘s a pool. Then, Mr. [B] said I will see stars and I will see comets and I will see- maybe a dwarf sun or something like that, m‘am. And then my Dad says different. He says if I go out to space I will just see blackness unless there is a planet in front of me. So that‘s why I say, m‘am, I don‘t- you see, it‘s confusing like that, m‘am…I would say that I believe Mr. [B], because if you look up you will see millions of stars so obviously if you go up to the stars it will be all around us…I believe Mr. [B], but, **I don't believe** that there‘s nothing there but planets. I don‘t believe that, m‘am." (Dyllan)

Table A4.1-6 (cont…)

Theme	Sub-categories of themes	Theme definition	Illustrative responses from the students
I DON'T BELIEVE	n/a	Scientists don't tell us the truth, and I don't believe what they say.	―…Scientists haven't been up close to Saturn and…you know the Voyager 2 or 1, I think it was the first one they sent out, that's only passing Pluto now…Maybe it's a long time past Pluto. That's another thing…That's what Mr. B- says...Voyager 1 that was sent out so they can experience our solar system, Mr. B- says it's only gone passed Pluto now…And that it's shut down because it works off solar power and now it's not getting any sun because it's past Pluto. So, maybe, **maybe it's not** past Pluto. I don't know…It's strange. Or maybe…as they passed Pluto another sun came so it was still on. It's quite confusing!…Say the Voyager 1 passed Pluto and now it's shut down, it's not getting any sunlight and now it's travelling for a long time and there's a planet that looks similar to Pluto or maybe has the same structure as Pluto and now they get sunlight again and they say, ―Ah, it it's just past Pluto, and it receives light from somewhere else." But it's not Pluto. It's like a different planet." (Dyllan)

Table A4.1-7: Range of **informed** views regarding the **socially- and culturally-embedded** aspect of NOS

Theme	**Sub-categories of themes**	**Theme definition**	**Illustrative responses from the students**
THINK DIFFERENTLY	n/a	Scientists have different ways of thinking and seeing things, different opinions, they believe different things, and they research different questions/views.	—Because **they all see it in a different way** and only God can tell what they really look like.” (Raashid) You take your facts and you‘d add your own opinion to it, to make sense of it, and then you make a story out of it that you tell people […And that‘s…why they might **disagree**, because…**they might have slightly different opinions**.]” (Victoria) —**Some of the scientists believe different facts** and that then makes them theories.” (Victoria)
DIFFERENT METHODS	n/a	Scientists have different ways of working.	—**Not every scientist works the same way**, that‘s why they disagree…Every scientist has **his own way** of making things. Each has his own mind and a **different method** to get to the answer...**Every scientist has a different method** that will suit to their kind [of work], like, it‘s easy for them to do [it] that [way]...They have to **find a method that suits the way they work**...” (Shafia) —They did the experiment differently. **I don’t think that every scientist should have to do the same experiment the same way**.” (Gideon)
DIFFERENT ANSWERS	n/a	It is possible for scientists to come up with different answers.	—They all do different research and **sometimes** find **different answers**...” (Samuel) —Because **one scientist could have proved one thing and the other proved the opposite**…e.g., One says we can live on the moon. Another says we can‘t take everything we need there.” (Gideon) —Resolve disagreements? They just accept **there will always be different answers**.” (Gideon)
RESOLVE DISAGREEMENTS	MAJORITY VOTE	In order to resolve their disagreements, scientists agree on the majority position.	—Different scientists say different things so you don‘t know who to believe. e.g., planets… [In order to decide who to believe] you have to maybe **find more scientists and see which one’s got most on their side**. Like, if there‘s only one scientist saying one thing and then there‘s three scientists saying another.” (Maya) —To decide who is right, maybe they use **majority**.” (Samuel)

Table A4.1-7 (cont…)

Theme	Sub-categories of themes	Theme definition	Illustrative responses from the students
RESOLVE DISAGREEMENTS	COMPILE ALL INFO	In order to resolve their disagreements, scientists put all their information together.	“[Different scientists] do [try to resolve their disagreements]. **They try to put the facts together**. Sometimes they‘ll just agree with the *other* scientist who has *more* information…” (Aaeesha) “**They should work together and try to put all the information together to get the right answer**. Different answers and methods are still part of science. They need to put all the information together to find the answer.” (Shafia)

Table A4.1-8: Range of **developing** views regarding the **socially- and culturally-embedded** aspect of NOS

Theme	Sub-categories of themes	Theme definition	Illustrative responses from the students
DIFFERENT CONCLUSIONS	DIFFERENT EVIDENCE & DIFFERENT CONCLUSIONS/ OPINIONS	Disagreements result from different evidence and from scientists‘ different conclusions/opinions.	“They‘re all…taking up the **different conclusions**, all of them, about the way the dinosaurs died….**Maybe they find different evidence**…Then they get confused and that…[If they had the same evidence they would come up with the same conclusions] more or less, but **maybe someone else could find something else about that evidence and make a different conclusion**, or even make a mistake.” (Raashid) “So the fact that they disagree shows you that there must be **different facts and** that there must be **different opinions** involved.” (Victoria)
	DIFFERENT EVIDENCE	Scientists might disagree if they find different evidence.	“Because **each one finds different facts**….” (Brian) “They have different ways of investigating and finding out facts. e.g., Some do interviews, some guess. There are different ways for different people…**Maybe if he found different facts in a different way**, from these other people, and he led to a different answer, but he may have not been accurate compared to them…or **he found different things**.” (Maya)
	NEW TECHNOLOGY	The use of new technology could cause scientists to disagree.	“[Re: If scientists disagree, it‘s] probably [because of] **new technology**.” (Dyllan)
	MISTAKES	Disagreements might be caused by someone making a mistake.	“They have different ways of investigating and finding out facts…Maybe if he found different facts in a different way…and he led to a different answer, but **he may have not been accurate compared to them**…or he found different things.” (Maya) “Everybody can make mistakes, even a scientist can come to **a wrong conclusion**…” (Raashid)

Table A4.1-8 (cont…)

Theme	Sub-categories of themes	Theme definition	Illustrative responses from the students
DISSOLVE DISAGREEMENTS	n/a	Disagreements are dissolved by searching for evidence, to determine the correct answer, or to find that there was only one answer.	“When they disagree: Then they search further what one says and what the other thinks (e.g., planets) **to see who is** correct…They look further to see if it‘s correct and find different stuff. Other scientists could check what other scientists say and see if it‘s right…**There might not even be an argument sometimes**: there may even be [only one answer], maybe even one version that everyone finds [so then there is no disagreement].” (Maya)
NO COLLABORATION	MISTRUST EACH OTHER	Scientists don‘t work together because they don‘t trust each other.	“….Each one finds different facts….[because] **they don’t like trusting each other**. They want to find out for themselves. **They don’t work together**.” (Brian)
	COMPETE FOR GLORY	Scientists don‘t work together because they compete for fame and glory.	“Everybody can make mistakes, even a scientist can come to a wrong conclusion. Sometimes they could be **lying** because they **want to be famous**.” (Raashid) “Because someone could tell them what [dinosaurs] look like and then they might find dinosaur fossils and the dinosaur looks different…i.e., They get all excited for nothing about a big bone, then they find there are more like it. One scientist might have said it was the only one so the others stop looking. He wants to make the others jealous. They **compete** for the biggest bone so they can be the one who is **famous**.” (Dan) [Re: Do you think that if all scientists have the facts they‘re going to come up with the same answers?] “No, I think they will just make excuses to say that they are wrong...[Just so that they can find out for themselves…**so that they can be the ones to have the…] glory or something**…” (Brian)

Table A4.1-9: Range of **naive** views regarding the **socially- and culturally-embedded** aspect of NOS

Theme	Sub-categories of themes	Theme definition	Illustrative responses from the students
NO DISAGREEMENTS	NOT OKAY	It is not okay that scientists disagree about things.	―[It‘s **not really okay that scientists disagree about things**] because…for instance, [if] I have a test. And my dad and I study for the test and I read out something that‘s given in our notes that we‘re gonna be tested on that says, [for example] that the Milky Way has twenty solar systems, and now my dad disagrees with that and he says it only has one. And then I write on my test ―One” and then I get marked wrong. And then that might just give me one mark off full marks, or I might fail because of that...” (Dyllan)
	ONE ANSWER	There is only one answer that scientists can arrive at.	[Re: Do scientists follow a fixed set of steps?] ―Well, it depends on what you‘re looking at, and it can be, but...if they take a dinosaur bone then you have to first dig it up, you know, but in some cases you can just choose where to start because **it really doesn't matter ‘cos you're going to get there (i.e., to the answer) anyway**.” (Shanon)
	SAME ANSWER	Eventually scientists will find that their different answers mean the same thing.	―One scientist will have different facts but eventually they‘re both right because they don‘t understand what the thing means then much later they figure out **it's actually the same**...Normally they can work out their disagreements.” (Aamir)
	SAME FACTS	If scientists all have the same facts then they won‘t disagree about things.	―**If they all have the same facts they wouldn't really disagree on things.** They would agree on things because the facts would be very similar.” (Victoria)
	MORE EVIDENCE NEEDED	When scientists disagree, they need to search for more evidence, and then their disagreements will be resolved.	―[Re: disagree] Sometimes they are not sure if their answers are correct…They find out more about the animal then they‘ll be sure about it. To find out more they go to archaeologists. Then they‘ll no longer disagree. They **disagree because they don't have enough facts** so they are unsure.” (Yamina) [Re: Disagreements] ―They **don't have enough facts**.” (Dyllan) ―[Scientists sometimes disagree] Because they are not very sure…They don‘t know everything…Sometimes half a way they search so they don‘t know everything...” (Reza)

Table A4.1-10: Range of **informed** views regarding the **imaginative and creative** aspect of NOS

Theme	Theme definition	Illustrative responses from the students
MISSING EVIDENCE	Scientists use their imaginations when there is evidence missing (e.g., an incomplete skeleton, or no skin left)	“[They use their imaginations] when they are trying to investigate something...e.g., Dinosaurs—muscles around the bone, and skin. The **dinosaur isn’t actually there for them to look at**.” (Victoria) “Science is about more than the facts. You need your own opinion and sometimes you must also use your imagination…Like the dinosaurs, they only had the bones but **with their imaginations they were able to tell us how they looked** (i.e., skin colour, etc.)…Skin colour is not there because the meat is all gone. It is only bones…**They need their imagination to put the information together**…Bones: when they dried their bones they came out the way they were (i.e., in the form of the skeleton in the ground). They put it together and **use their imagination to work out how they look**: skin colour and skin type (i.e., scaly or smooth).” (Shafia)
BUILT ON FACTS	They find the facts and then use their imaginations to determine the rest.	“[What scientists think is also part of science] because sometimes they have to use their imagination, like for pictures and artefacts, they need to find out, they have to use their imagination a bit…**they find out facts and then they use**...e.g., A piece of clay: it must be pottery; A piece of gold: must have been jewellery...” (Maya) “**They picture what the creature or thing looked like**...If they don‘t know what the creature looked like they‘ll listen to the name and try to picture what it looked like. **They use different animals that have a similar sounding name**. Then they‘ll use a part of that animal to the animal that they are studying...” (Yamina)
TRY DIFFERENT OPTIONS	They are using their imaginations when they just try different options to see what works best.	“When, for example, they put a dinosaur back together…You have no clue what it‘s going to look like. They use their imaginations to **try lots of different ways** until they get what they think the dinosaur looked like.” (Gideon) “[They base their stuff on] maybe something that they‘ve seen before? [And electricity is based on]…Like, with plugs and maybe they want to make something with a motor in that moves. [In order to know what to do] they just experiment. **They just, like, put a motor together and they think maybe you join this wire to that wire**…and then…[They just try different options].” (Dan)
INVENTING & CREATING	Scientists use their imaginations and creativity when they are inventing and creating something new.	“…sometimes, when they are **creating things**, they use imagination…If they‘re **inventing** something then it‘s okay that they use their imaginations.” (Shanon) “They might use their imagination when they **design a new** machine or liquid.” (Dan)

Table A4.1-10 (cont…)

Theme	Theme definition	Illustrative responses from the students
INVENTING & CREATING	Scientists use their imaginations and creativity when they are inventing and creating something new.	~~"~~[They use their imaginations/creativity] when they are **creating something** (i.e., what the thing looks like, etc.)...e.g., Toasters (different styles), Cars (different types and colours and looks)...e.g., experiments—make medicine. They try stuff to see if it will work. e.g., cure of AIDS; e.g., structures." (Raashid)
NAMING SPECIES	Their imaginations are involved when they give a name to an animal.	~~"~~Sometimes maybe when they study animals that were extinct long ago and say how it looked and **name it** according to how it looked…(Aaeesha)

Table A4.1-11: Range of **naive** views regarding the **imaginative and creative** aspect of NOS

Theme	Theme definition	Illustrative responses from the students
TRUTH	Scientists need to find the truth; imagination is fiction.	[Re: Do scientists use their imaginations/creativity?] ―Well, I hope not, because then every ‗scientific‘ fact will be rubbish. **Scientists need to find the truth**, not the imagination in their heads.” (Shanon) ―No...Because when you use your imagination it is **fiction**.” (Brian)
NEED PROOF	Scientists can‘t use imagination if they are doing an investigation; they need proof.	[Re: Scientists‘ use of imagination/creativity] ―It‘s not okay if they‘re trying to **prove** something.” (Shanon) ―They have to work with facts that have **proven** to be true. If they use their creativity the facts will not be true and their investigation will be made up…” (Samuel) ―Not when they discover history. You can‘t just take guesses and use your imagination. You need **proof**, e.g.,what people looked like. [Also] e.g., not when they do investigations.” (Raashid)
NO EXTRAS ADDED	They can‘t add in extras to the facts.	―…when they gather everything…all the information…then they go on the presentation and all that…**They won't put** extra, I think so, scientists, they won‘t put extra things in there…**Not [things that they have] thought**, they have to look [otherwise the other people will] say, ‗No, that‘s lie, they‘re talking lies about it‘…” (Reza)
REMEMBERING	Their minds ‗run wild‘ when they are trying to remember things they have learnt before.	―Their minds run wild when they‘re thinking about the stuff that they want to do, and when they are busy with work that they like. That‘s actually better because then they get more answers to their things...It will help you because, like, I might know the stuff but I might see one word on the page so I might remember it...Sometimes they might have learnt that a long time (ago) already, but then they might learn it again but then they don‘t **remember the things that they learnt**. So they might remember a few stuff so… then it will carry on...[So it‘s running wild remembering things that were before]…” (Aamir)
PRESENTATIONS	Scientists are creative when the present their facts nicely to people.	―Ja, **when they present**, you can‘t just, like, you searched everything, ja,…put it there…you can‘t present it quickly, **have to make it nicely, we have to put pictures on**…like, if there‘s a egg here, you can‘t put the nest here and the water here…you have to put the egg and the nest next to each other…so they have to present it…here‘s a piece and what‘s continuing…[to] make more sense…go here and then there… When they present it, because when they search you can‘t…lose time, create, okay, **make a border, make everything right, make a picture**… when they gather everything…all the information…then they go on the presentation and all that…” (Reza)

Appendix 4.2
NOS PROFILE OF EACH OF THE REMAINING CASES (ARRANGED ALPHABETICALLY)

BRIAN

- The facts don‘t change—and if they did change scientists wouldn‘t tell us about it—otherwise people won‘t believe scientists
- Scientists go to places, they observe things, and they also make discoveries and create inventions
- Some of science is made-up stories, which based on what they think not what will actually happen, but when you use your imagination it is fiction; made-up stories are not real science because they don‘t sound plausible, and the stories need to be checked and they need to be consistent with the evidence; stories of scientists that work for the government are true; other scientists make up stories so that people will think they are clever or correct—they might be sure of what they tell us but we‘re not certain about it
- Scientists don‘t trust each other or work together—they disagree because they find different facts and perhaps they want to be the one to have the glory

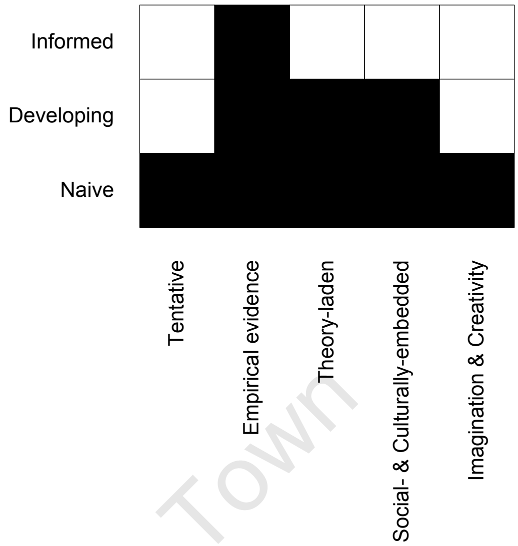


Figure A4.2-1: Synopsis of Brian‘s NOS profile

DAN

- Scientists create new machines
- What they tell us is based on things they‘ve seen or experiments they have done
- Opinions are part of inventions, and this is where scientists use their imaginations/creativity; facts can be found on the Internet
- Scientists try their own ways of doing their experiments, but competition and a desire to be famous undermines rigour in searching for all possible evidence.

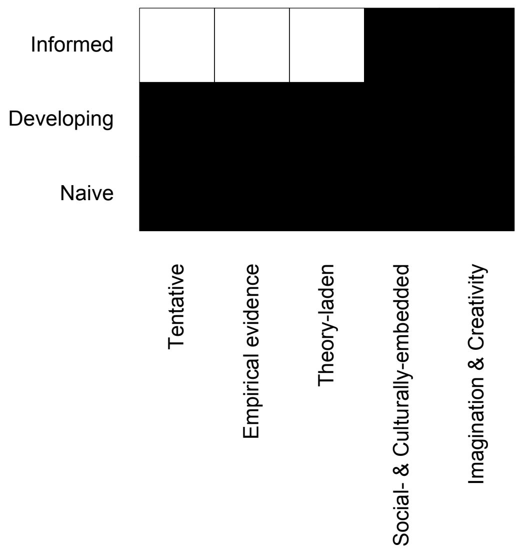


Figure A4.2-2: Synopsis of Dan‘s NOS profile

DYLLAN

- With the help of new technology, scientists can change what they say—maybe they find they were wrong
- If scientists disagree it‘s because of insufficient facts or new technology, but it‘s not okay for them to disagree
- Scientists do chemical tests in their lab and they use technology;
- They don‘t have all the evidence about dinosaurs so they might be using their imaginations and fooling us;
- They take pictures of space but they don‘t really study space, and they might be incorrect or tricking us;
- I don‘t believe what scientists tell us; I also don‘t believe some things that my Dad says.

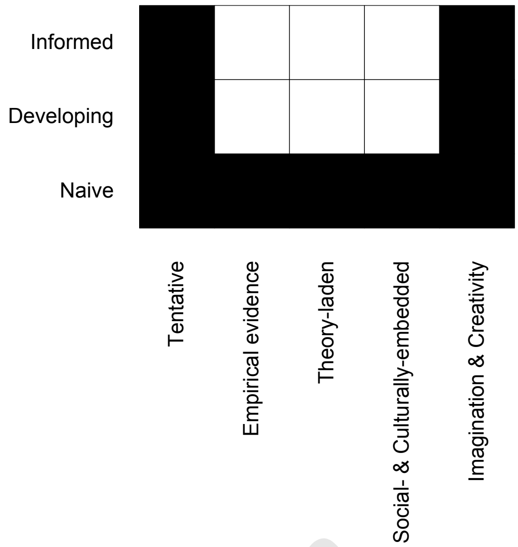


Figure A4.2-3: Synopsis of Dyllan‘s NOS profile

GIDEON

- Everything has to change eventually, so there‘s a good chance scientists will change their minds and tell us different things in the future
- Scientists do experiments to prove their answers so that it can become fact
- Myths (things that people thought to be true) aren‘t part of science until they‘ve been confirmed
- Scientists do their experiments in different ways, and there will always be different answers
- Scientists use their imaginations and creativity in trying different ways to reconstruct a dinosaur skeleton until they get what they think it looked like.

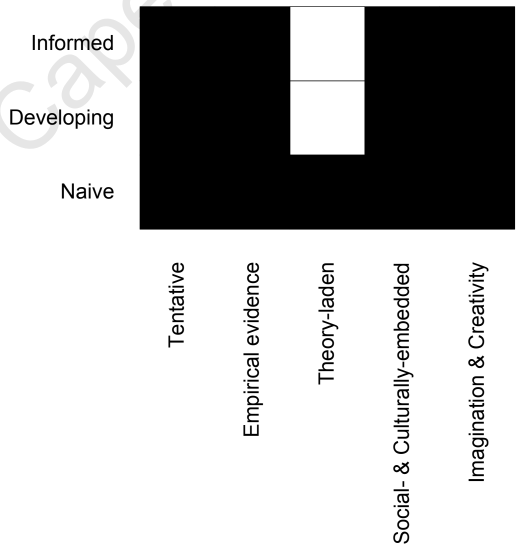


Figure A4.2-4: Synopsis of Gideon‘s NOS profile

MAYA

- Scientists investigate and gather information, and they are certain when they have finished investigating.
- What they say could change if they look further and find more facts.
- When there are gaps in the facts, scientists use their imaginations and thoughts to make inferences based on the facts. But they rather collect more facts than make guesses, as guesses aren‘t based on facts.
- When scientists disagree, it is because they have different facts or have made errors using different methods—disagreements are resolved by finding more facts.

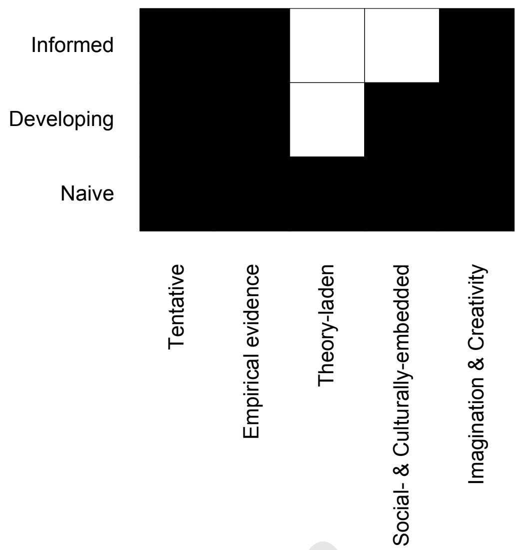


Figure A4.2-5: Synopsis of Maya‘s NOS profile

RAASHID

- In line with advances in technology, scientists might change what they tell us; or scientists could make a mistake in what they tell us about the past (they weren‘t there at the time, only God knows); scientists can‘t tell us about the future (only God knows)
- Scientists discover stuff and they create new things
- Disagreements are due to different evidence and therefore different conclusions, mistakes, or scientists telling lies (in order to be famous)

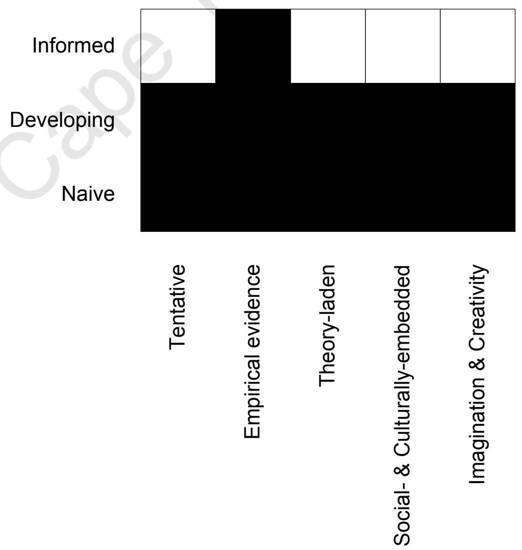


Figure A4.2-6: Synopsis of Raashid‘s NOS profile

REZA

- Facts don‘t change so we can pass them onto the next generation
- Scientists work hard, going to different places and searching for evidence—although I don‘t know how scientists do their investigations
- If scientists disagree it‘s because they don‘t know everything, so they need to continue searching until they find/know everything—then they can tell people
- Creativity is involved when scientists present things nicely to people

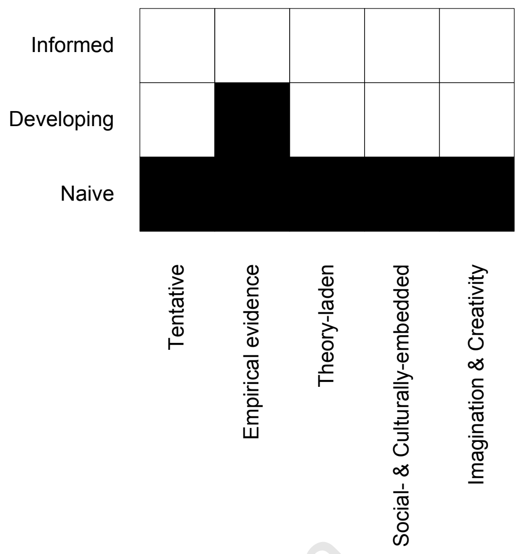


Figure A4.2-7: Synopsis of Reza‘s NOS profile

SAMUEL

- Scientists might investigate their ideas/opinions and change their minds about what they thought before
- Scientists research things in a laboratory or they work at the location of whatever they are studying
- Most of science is based on facts, but sometimes scientists estimate/guess to fit in with their facts and when there is evidence missing
- Science involves different people‘s opinions, and different answers arise from the use of different methods
- Scientists can‘t use their creativity, because then the facts will not be true—they have to work with facts that have proven to be true

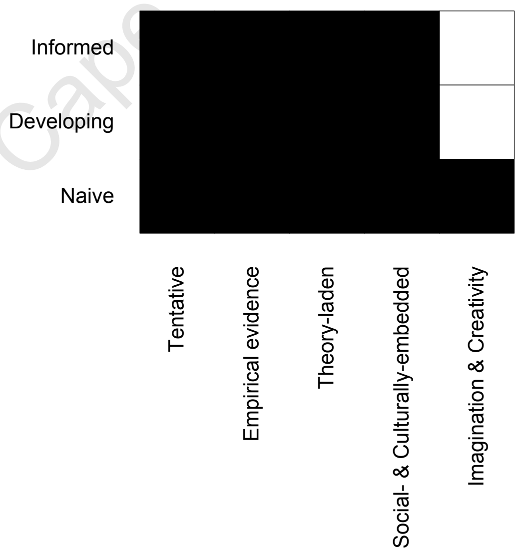


Figure A4.2-8: Synopsis of Samuel‘s NOS profile

SHAFIA

- Scientists do research – they search for the thing they are studying, observe, check a sample in the lab.
- We trust them if they have enough facts, but sometimes they only have a few facts – then they use their own opinion and imagination, and they could be wrong, so then we‘re not sure if we trust them.
- Different scientists have different methods and different answers, so they disagree – they put together all the information to find the answer.
- Facts can change because scientists sometimes make mistakes.

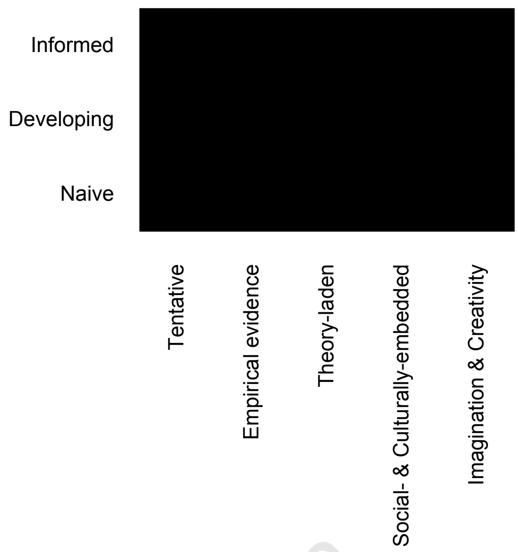


Figure A4.2-9: Synopsis of Shafia‘s NOS profile

SHANON

- Scientists use their imaginations to develop things to make the world more advanced and to improve our lives; they triple-check before publicizing information in order to avoid mistakes
- Scientists use tools and analyse closely, and they to prove the right thing/find the truth;
- But we don‘t know exactly what they use—so they could be bad people/corrupt businessmen and sell the wrong idea; if they make a mistake, hopefully it is an innocent error
- Scientists have different theories and different methods so they get different answers—although they will arrive at the same answer despite the various steps they might take.

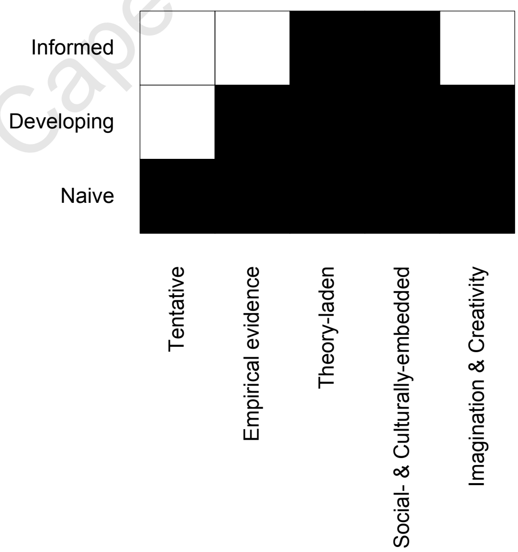


Figure A4.2-10: Synopsis of Shanon‘s NOS profile

VICTORIA

- Scientists might find new information and then the old facts won‘t be relevant any more
- Scientists study different types of things, they find things and test their theories, to make facts about them
- Some things scientists haven‘t seen for themselves, and they have their own opinions and believe different facts—they simplify things in their own way to make it understandable for us—you believe the scientist who makes the most sense to you
- The fact that scientists disagree shows that there are different facts and different opinions involved in science
- Scientists use their imaginations when they investigate something that isn‘t there for them to look at

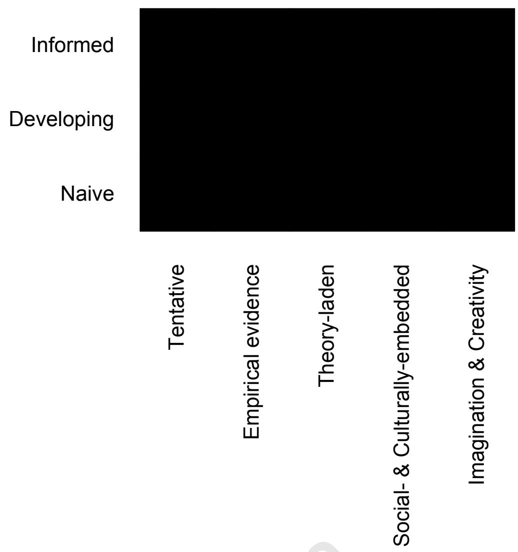


Figure A4.2-11: Synopsis of Victoria‘s NOS profile

YAMINA

- The things that scientists tell us won‘t change
- Scientists study evidence and so we can believe what they say, although they might be deliberately deceitful so sometimes we can‘t trust them
- Science is mainly based on evidence/facts (―truth”) but also includes scientists‘ ideas/thoughts (―facts”)
- Scientists disagree if they don‘t have enough facts so they are unsure
- Scientists use their imaginations/creativity to visualize past species, based on present species

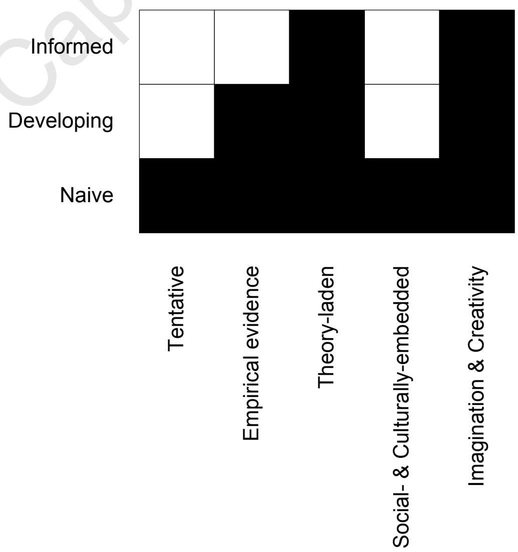


Figure A4.2-12: Synopsis of Yamina‘s NOS profile

Appendix 4.3
RANGE OF STUDENT RESPONSES RELATING TO EACH OF THE FOUR WORLDVIEW DESCRIPTIONS

1. Epistemological descriptions

The range of knowable and unknowable views described by the students, were organised according to four themes, namely, 1) Can we know things about Nature?, 2) Is Nature predictable?, 3) Is there order in Nature?, and, 4) Is there a reason for things that happen in Nature?

Table A4.3-1: Can we know things about Nature?

Nature is understandable *(Knowable)*	Differentiating between things (e.g., controlled vs. wild fire, different animals and their names, different water sources) (Dan, Brian); Knowing about leaves and how they obtain water (Maya; Understanding how cows digest grass (Aaeesha); Understanding the relationship between fynbos and fire (Dyllan); Learning easily about Nature when it is explained by other people (Aamir, Brian).
We can find out things about Nature (*Knowable)*	Going to Nature, and seeing and experiencing things (Shafia, Samuel, Dyllan, Victoria)—anyone can do this (Samuel, Yamina); Doing research (Yamina, Victoria); Working in a lab (Samuel) and testing samples (Victoria); Using technology (Aaeesha)—although technology is limited in not yet enabling exploration of another universe (Raashid). Not needing to go to Nature or to specialise in studying Nature (Raashid); Reading books (Shafia, Maya, Raashid); Watching television documentaries (Shafia, Raashid, Dan); Searching on the computer and Internet (Samuel, Dan, Dyllan); Learning things at school (Shafia, Samuel, Dan, Brian); Asking a parent (Reza); Asking people who have studied Nature (Shaifa, Maya) or finding out from practitioners who work with Nature (e.g., farmers) (Dyllan).
Scientists study Nature *(Knowable)*	Learning about Nature in the field of science (Samuel, Dyllan); Learning about Nature from a Natural Science teacher (Samuel, Yamina, Aaeesha, Dyllan); Scientists study Nature (Shafia, Samuel, Gideon, Aaeesha, Aamir, Victoria, Brian): Archaeologists (Raashid, Dyllan), biologists (Shanon, Raashid), botanists (Shanon, Maya), zoologists and environmentalists (Shanon); Learning about Nature in Social Science at school (e.g., climates, grasslands and volcanoes) (Shafia).

Table A4.3-1 (cont.)

We need to learn about Nature *(Knowable)*	*Survival* Needing to survive in Nature for a while (e.g., how to make a fire, build a shelter, find water, and knowing the various plants/animals in the local surroundings); Needing to know how to use plants for natural remedies/medicines (Aamir); Needing to find a new planet to live (i.e., after Earth has been destroyed by global warming) (Brian). *Protect Nature* Using our knowledge of Nature to protect Nature and stop pollution (Shafia, Samuel)—although it is too late as the problems have already been caused (e.g., global warming) (Shanon). *Studying the past* Needing to know about the San/Khoikhoi in the past (Reza); Knowing about past discoveries that people have made (e.g., consuming cow's milk, how germs are spread, the invention of anaesthetic) (Raashid); Archaeologists digging up bones and finding fossils (Raashid, Dyllan). *Legacy of knowledge* Needing to study Nature and pass on the knowledge to the next generation, so that other people can continue knowing about Nature (Aamir, Shafia, Reza).
Nature is diverse and comprises a mixture of different things *(Unknowable)*	Nature comprises various components, such as plant and animal life (Yamina, Brian) and Earth/soil, as well as different types of natural locations (e.g., open/undeveloped space, jungle, swamps, wild spaces, countryside, city) (Maya); Different types of gardens (Yamina). Diversity roles of species in an ecosystem (e.g., bee, cow, lion, vulture, hyena) (Dyllan); Some things are themselves a mixture (e.g., "~~a~~ baby is a mixture of blood and sperm") (Raashid); It is difficult to memorise the names of all the different things (Aamir); Diverse sizes in Nature—large (e.g., sea) vs. small species (e.g., ants) (Raashid); Diverse states of matter—solids vs. liquids (e.g., water) (Raashid).
Nature is confusing, complicated, and difficult to understand *(Unknowable)*	Understanding the process whereby Nature was formed (there are many alternative explanations) (Shanon); Understanding how various natural disasters begin (e.g., tornado, volcano, hurricane, fire) (Samuel, Gideon, Dyllan); Finding out about high/low tides in the ocean (Samuel); Understanding ice (e.g., water freezing to become ice, icebergs not melting in the sun) (Gideon, Victoria); Understanding water seepage from rocks (e.g., Cango Caves) (Aaeesha); Understanding metals in different phases (i.e., liquids and solids) (Aaeesha); Understanding the preferred growing conditions/locations of various plants (Aamir); Understand how living organisms grow and function (e.g., various stages of seed growth, fish that lay eggs from their mouths) (Victoria, Aaeesha); Knowing about poisonous flowers on the mountain (Reza); Understanding a pet dog's recurring ear infection (Dyllan).
Hard work and much time *(Unknowable)*	Finding out about Nature is hard work and requires much time to discover and understand everything (Aamir, Shafia, Reza, Raashid).
Undiscovered things in Nature *(Unknowable)*	There is much more to discover in Nature (Aaeesha, Raashid), and we need better technology in order to do this (Raashid); Undiscovered animals/creatures (Samuel, Yamina, Brian), viruses, and planets (Brian).

Table A4.3-1 (cont.)

Changes in Nature *(Unknowable)*	Changes in weather (Maya, Samuel) and global warming (Shafia); Climate change and subsequent extinctions of species (Shanon); Changes that occur in animals and plants (Shafia, Samuel); Changing seasons (Maya, Samuel), colours, fruit ripening, species dying (Maya); Natural disasters (Shanon, Aaeesha), wind turning into tornadoes (Gideon); Changing tides and ocean currents (Shanon, Samuel); Changing deserts, mountains and rocks (Shanon, Samuel); Sand turning into diamonds, water turning into ice (Gideon); Forests catching fire (Dan); The Big Bang and continental drift (Aaeesha),; People evolving from cavemen to modern day man (Gideon); The world coming to an end (Dyllan).

Table A4.3-2: Is Nature predictable?

Nature is unpredictable *(Unknowable)*	Tsunamis (Aamir, Shanon) and volcanoes (Shanon, Yamina); The weather (Yamina, Victoria) and global warming (Shafia); An ability to predict Nature requires great intelligence (Raashid); People cannot know what will happen in the future—only God knows (Reza).
Nature is predictable *(Knowable)*	An eclipse is predicted to take place in 2012 (when Venus will cover the sun) (Dyllan).
Nature is both unpredictable and predictable *(Knowable & Unknowable)*	Unpredictable events/phenomena include: tornadoes (Samuel, Gideon, Dan), earthquakes (Samuel, Aaeesha), weather, lightning and storms (Maya, Samuel), hurricanes (Maya), ice and fire (Gideon), volcanoes (Gideon, Dan); Predictable events/phenomena include: the natural order of cause-effect (Dan), the seasons (Samuel), and satellite weather predictions (Maya).

Table A4.3-3: Is there order in Nature?

Nature is orderly *(Knowable)*	Food chains and interdependence within ecosystems (e.g., bees pollinating flowers to create honey, animals needing each other for survival (Aamir, Aaeesha, Raashid, Dyllan); Interactions between various animal species (e.g., lion is ―king of the jungle and control[s]" the other animals) (Aaeesha, Dyllan); Things that happen in stages and cycles (Aamir), such as the growth stages of a plant (Victoria, Yamina), butterfly lifecycle (Victoria), and set processes in Nature (e.g., how flowers unravel slowly when they bloom) (Victoria). The seasons are cyclical (Maya); Cause-effect (e.g., birds mating and laying eggs, tornado caused by wind) (Dan); The necessary time lapse between an animal giving birth, mating again and bearing new offspring again (Gideon); Order in Nature enables people to predict future events (e.g., eclipse) (Dyllan); Nature is only chaotic when people become involved and disturb the natural order (e.g., a naughty boy disturbing a herd of grazing animals, causing them to run through the village and create hysteria amongst the people) (Yamina).

Table A4.3-3 (cont…)

Nature is chaotic and lacks order *(Unknowable)*	Storms, lightning, thunder (Maya), tsunamis (Shanon), tornado (Gideon), floods (Shanon), and wildfires (Shanon, Victoria); Animals fighting over food (Shanon) or fighting over a mate (Dan); Food chains (e.g., when animals are equally matched in their position in the food chain, so it is unsure which species will eat which) (Raashid); Nature does not grow in orderly rows (Reza, Brian)— “it just grows...everywhere” (Brian), a mixture of different things are found in different places (Reza) and events take place in different times in different places and involving different things (Shafia); Events occurring simultaneously (Samuel) (e.g., during a volcano eruption – the volcano erupts, things burn on one side, and “stuff shoot[s] out the top”) (Dan); Unpredictability of events (Shafia).

Table A4.3-4: Is there a reason for things that happen in Nature?

Things happen for a purpose or reason *(Knowable)*	Rain clears/cleans animal burrows and acts as a warning for some animals, species are eaten in order to feed others (e.g., worm and bird) (Victoria); Everything on Earth has a reason/purpose (e.g., for us to use it), but we first need to find the purpose (Shafia)—although “you can‘t always figure it out” (Shanon); There might be a purpose that we do not know (e.g., diamonds might enhance the ground in some way) (Raashid); We might not be able to know the purpose of natural phenomena (Raashid) (e.g., storms might occur in order to water the plants and fill dams, or they might be sent by God) (Yamina).
No reason *(Unknowable)*	There is no reason for natural events (e.g., volcanic eruptions) (Dan).

2. Ontological descriptions

The range of naturalistic and super-naturalistic world descriptions articulated by the students were organised according to seven themes, namely, 1) What is the origin of Nature? 2) Is Nature holy and spiritual?, 3) Is there a purpose for things that happen in Nature?, 4) What are the processes that occur in Nature?, 5) Can we see and touch things in Nature?, 6) Is there transcendental involvement in Nature? and, 7) Is Nature an animate being with a personality?

Table A4.3-5: What is the origin of Nature?

Created by God *(Super-naturalistic)*	In all cases (except Dyllan) students described the view that God created Nature—although two students were not completely certain of this (Gideon, Victoria).
Created by Nature *(Naturalistic)*	Things in the natural world have been created “by Nature” (Dyllan, Brian) or by the Earth (Gideon).
Created, but controls itself *(Naturalistic and Super-naturalistic)*	God created the Earth, but Nature now controls itself (Gideon) and is “doing its own thing” (Maya).

Table A4.3-6: Is Nature holy and spiritual?

Holy *(Super-naturalistic)*	Nature is holy “because God created the Earth” (Victoria); Plants and animals pray to God (Shafia, Aaeesha), and people can pray to beautiful things in Nature (e.g., diamonds) (Dan); The natural order of animals illustrates how Nature is holy and revered (e.g., vultures respect the lions as “king of the jungle”) (Dyllan).
Not holy *(Naturalistic)*	Although God is holy and He created Nature (Maya, Raashid), Nature itself is not holy “because it doesn‘t really have a culture” (Gideon), and “it is not holy like [the] Q'uran” (Reza); The students did not pray to Nature or worship Nature (they prayed in church, and worshipped God) (Brian, Aamir, Raashid); Plants do not worship or pray to anything, or perform a ritual cleansing for a god (Yamina); Nature might be considered holy for religions other than the students‘ own religion (e.g., people who regard the cow as a very holy creature (Samuel, Raashid).
Spiritual *(Super-naturalistic)*	Nature is spiritual “because *Hashem* [God] created it” (Maya); “If you pray a lot and you thank God for your food” then God will protect you (e.g., if a lion comes to your house) (Dyllan); It is *haram* (forbidden) for Muslims to touch dogs, and if it happens then ritual washing is required (Reza); Nature can be spiritual in regard to using herbs for healing, as “part of your religion” (Dan); Enjoyment of Nature (e.g., it is beautiful, and “[it] feels free, open and fresh”) (Shanon and Shafia); Calming and relaxing effects of being alone and surrounded by peaceful Nature (e.g., at the sea, fishing, sitting under a tree in the Kalahari Desert, lying on the grass in a breeze, and looking up at the clouds) (Samuel, Raashid, Dan, Victoria); Nature exerts a calming and relaxing influence, simply by thinking about it (Gideon); Nature helps to calm the emotions and improve a person‘s mood (Shanon).
Not spiritual *(Naturalistic)*	There is no spirit in the trees, and trees will not “come alive” through chanting/meditation (Brian); Spirituality is associated with rituals (e.g., sacrificing cows, playing drums, singing songs, etc.) (Dyllan); A spiritual place means a place of stillness, but one student did not choose to seek quietness by, for example, going to read a book under a tree (Aamir).

Table A4.3-7: Is there a purpose for things that happen in Nature?

Super-naturalistic/ transcendental purpose *(Super-naturalistic)*	Severe weather phenomena (e.g., tsunamis and volcanoes) —happen for a purpose, linking them to spirituality” (Shanon); Natural disasters are possibly sent by God as punishment (Aaeesha, Raashid)— —God] controls everything...maybe [He] sent the storm” (Yamina); The idea of karma was offered as a possible explanation for why a former school bully was hit by a car and left comatose (Gideon).
Naturalistic views *(Naturalistic)*	In Nature —nothing happens for a purpose” (Samuel, Brian); Natural events take place for physical reasons, for example: Earthquakes result from plates moving in the Earth, and drought occurs as a result of ozone layer damage (Samuel); Fires are caused by glass on a hot day or by naughty people, or to stimulate new plant growth (Aaeesha); Rainstorms occur to provide water for living things to fill dams (Samuel, Yamina); Ice melts in order to provide water for animals to live (Gideon); Vultures kill animals due to hunger, fossils died from old age, bees die after stinging in order to save themselves the pain of being killed by some other means, an egg is created by two birds mating, and a tornado is caused by wind (Gideon); Things have a purpose in Nature because everything is linked in a cycle (e.g., the food chain, bees pollinating plants) (Raashid); Nature was created —for [the] purpose [that we] use it” (Victoria).

Table A4.3-8: What are the processes that occur in Nature?

Physical causes and processes *(Naturalistic)*	Natural phenomena have physical causes/undergo physical processed, for example: Mountains (formed by different minerals over time) (Shanon, Samuel, Victoria); Natural disasters, such as earthquakes, tsunamis, volcanoes, tornadoes, wildfires) (due to changes happening within the earth, such as the movement of plates) (Aamir, Shafia, Shanon, Maya, Aaeesha, Dan, Victoria); Floods (caused by the moon) (Aamir); Rock falls (triggered by a loose rock falling) (Victoria); Changes in the weather result in the extinction of certain animal species (e.g., dinosaurs, dodo, quagga) (Shanon); Creatures are killed as food for hungry predators (Victoria); —There's always something to make something happen in Nature” (e.g., rain, the cycle of the seasons) (Maya).

Table A4.3-9: Can we see and touch things in Nature?

Things we can see and touch *(Naturalistic)*	Nature comprises living creatures and things that grow (e.g., trees, animals) and move (Aamir, Yamina, Dan, Brian); We can see plant life (e.g., trees, flowers) and animal life (e.g., eggs, birds), and places (e.g., deserts) in Nature (Samuel, Dan, Brian)—although a microscope is needed in order to see the smallest things (Shafia); We can smell things (e.g., plants) (Brian). We can hear things in Nature (e.g., a lion roaring, bees buzzing, a tornado destroying things, a fire, birds calling) (Dan); Some parts of Nature are tangible (e.g., fruit, flowers, plants, rain, sand, birds, fossils, eggs, animals, cows) (Shafia, Samuel, Dan, Dyllan, Brian)—and at times, painful (e.g., bee stings, being knocked by a rhinoceros) (Brian).
Things we cannot see and touch *(Naturalistic)*	We cannot see or touch air (Aamir, Shafia, Shanon, Aaeesha, Brian)—although we know it is around us (Victoria); We cannot see tiny molecules (Shanon), such as germs (Aamir); We cannot see people who are deceased (Aamir). Some parts of Nature we cannot touch, because: They are too far away (e.g., clouds, sun and moon) (Aaeesha); They are dangerous (e.g., fierce animals, lions, tornado) (Aaeesha, Dyllan); Some parts of Nature are too big to touch it all at once (e.g., Amazon jungle) (Dyllan).

Table A4.3-10: Is there transcendental involvement in Nature?

Super-naturalistic elements in Nature *(Super-naturalistic)*	Super-natural places: Heaven and hell (Reza, Raashid); Super-natural beings: Ghosts (Reza, Raashid), the devil (Reza); Super-natural events: The end of the world (the Last day of judgment) (Shafia, Reza); God controls everything in Nature (e.g., what is destroyed and/or repaired) and only He knows what will happen (Reza).

Table A4.3-11: Is Nature an animate being with a personality?

A sentient being *(Super-naturalistic)*	Nature is an emotive being with its own power and benevolent intentions (Victoria): ―…A a rock might fall and hit your head, but it‘s not saying, ―Ooh, look, there‘s [Victoria], doef”.[45] The rock falls because of a stone tumbling, and then it might hit a bigger rock and it goes into a bigger rock and so on. Even if you tread on a splinter, it‘s your own fault. Nature is a psychological being which has feelings. It doesn‘t reach out and scare you or harm you, so you can‘t really blame Nature for your bruises and cuts. Instead, Nature finds its own way to help you, like, if you‘re stuck in a forest and it‘s raining, [then] there‘s a cave and it‘s empty and you need shelter. Nature has its own power…it knows what it‘s doing.”
No personal emotions or thoughts *(Naturalistic)*	Nature ―doesn't have a heart” (Gideon); Nature does not have its own thoughts—it ―just does anything that could happen” (Brian).

3. Emotional descriptions

The range of positive-negative views described by the students were organised according to main themes, namely, 1) Is Nature enjoyable and appealing?, 2) Is Nature interesting?, and, 3) Is Nature dangerous, destructive and frightening, or is it peaceful and helpful?

[45] The sound made by the rock as it falls and hits a person.

Table A4.3-12: Is nature enjoyable and appealing?

Nature is likeable and enjoyable *(Positive)*	Examples included references to likeable animals and plants in Nature, enjoyable places and activities in Nature, and enjoying life because we have Nature (Table A4.3-13).
Unappealing *(Negative)*	Nature is too effeminate (Aamir): “I don‘t like Nature because it‘s too “girlie”. Like, if a boy goes into a forest he will try and break sticks and things. If a girl is there she will pick flowers and take them home and make something out of it.”
Beautiful *(Positive)*	Natural life (e.g., plants and flowers) (Reza, Samuel, Yamina, Aaeesha, Dan, Victoria); Natural forms (e.g., mountains) (Reza); Natural colours (Maya, Reza); Natural environments, such as the marine environment (e.g., fish, the sea) (Reza, Shanon). Natural events (e.g., Volcanic eruptions) (Gideon) and the spiral clouds of a tornado—from a distance (Gideon, Dan). Natural processes and products (e.g., the formation of diamonds, and ice (Maya, Gideon, Dan); Things are beautiful in Nature “because God made it” (Reza, Shanon, Samuel, Raashid, Gideon) “What makes [Nature] beautiful is that it is not perfect. There‘s flaws in it and those are the things that make it so beautiful” (Shanon). As a result of an appreciation of beauty in Nature, one student enjoyed photographing Nature (e.g., at Kruger National Park) (Dyllan).
Colourful *(Positive)*	Flowers and trees; Identifying different colours in a single scene (Maya), and the “different colours of water” in the sea (Reza); “My...very colourful” garden (Aaeesha).
Too colourful *(Negative)*	Nature is too colourful (Aamir).
Delicious *(Positive)*	Fruit (e.g., bananas, mangoes) (Raashid, Dyllan); Fresh fruit juice (e.g., strawberry) (Yamina); “My garden smells delicious” (Aaeesha).

Table A4.3-13: Examples of the students' references to likeable and enjoyable aspects of the natural world

Themes of responses	**Illustrations of responses from the students**	**Cases**
Animals & Plants	Insects are nice	Raashid
	Kittens and puppies are cute	Yamina
	I like roses	Yamina
	To see plants growing and creatures jumping around	Yamina
Places	Going on trips, visiting a place outdoors	Samuel, Victoria
	Go on outings (e.g., to Kirstenbosch Botanical Gardens, travelling along Boyes' Drive, exploring the Cango caves, visiting the Two Oceans Aquarium)	Samuel
	Go on the mountain, visit places on holiday (e.g., Montagu hot springs and Goudini Spa)	Reza
	Experiencing Nature (e.g., seeing an elephant or hearing a lion roar)	Dyllan
	To the beach, seeing the fish underwater	Samuel, Victoria
	The desert	Victoria
	Green places and the jungle	Victoria, Dyllan
	Walking my dog	Samuel
	Family garden	Maya, Samuel, Aaeesha
	Being in Nature, sitting and listening	Maya
	It is a warm, happy place to be	Shafia
Activities	Playing sports, playing with my cat	Aaeesha
	Have fun in Nature, play in the park	Dyllan
	Camping and to be outdoors	Maya
	Swimming	Maya, Samuel, Victoria
	Playing with fire	Dan
	We should spend more time in Nature rather than indoors, or with television/computer—appreciating what Nature has to offer	Samuel
Enjoying life	I enjoy the fact that you have it	Shanon
	It is a nice part of life	Maya
	We enjoy ourselves in everyday life because of Nature	Reza
	Without Nature the world would just be horrible and boring	Gideon
	We need to protect Nature then we can start having more things to enjoy about Nature	Brian

Table A4.3-14: Is Nature interesting?

Amazing[46] *(Positive)*	Large-scale natural phenomena (e.g., tornadoes, volcanoes) (Samuel); The variety of species that exists (e.g., various species of flowers and birds (Shafia); Particular species (e.g., sharks) (Shanon).
Fascinating / interesting[47] (*Positive)*	Animal life (e.g., insects) (Yamina) and the variety of living thins in Nature (e.g., flowers, birds) (Shafia); Animal adaptations (Shafia) and interactions between species (e.g., how the lion manages the jungle) (Aaeesha); Evidence of pre-historic animal life (e.g., fossils) (Yamina); Natural processes, such as, for example the formation of diamonds (Gideon, Dyllan), volcanoes (Yamina) and tornadoes (Dan), and the melting of icebergs and rising sea levels (Aaeesha); Discoveries (e.g., new animal species) (Samuel, Brian) and learning about Nature (Dan)—although having some mysteries unsolved keeps Nature fascinating and increases our enjoyment of it (Victoria); Natural resources (e.g., how everything is provided for us in Nature) (Samuel).
Boring *(Negative)*	Nature is boring ―because you see almost the same thing every day" (e.g., most of the trees look the same) (Aamir).
Intelligent *(Positive)*	Animals are intelligent (e.g., monkeys) (Raashid).
Everyday, ordinary *(Neutral)*	Nature is just there, all around us (Samuel); People can go to Nature everyday (e.g., playing in the garden) (Samuel, Gideon) and at any time (e.g., going to the beach); Wherever one goes there will be sand, stones, trees, and so forth (Gideon); There is much of everything to be seen in Nature (trees, flowers, eggs, animals like birds) (Brian)—familiarity with Nature makes it ordinary (Gideon, Brian).
Not ordinary *(Positive)*	Nature is not ordinary, because of the variety of plant and animal species, and the various types of natural settings (Maya); Different things can be seen every day (Dan); Nature is not just there because ―you gave to go *to* Nature" (Dan).

[46] Descriptions of nature as ―amazing" indicated a sense of wonderment and being impressed by Nature.
[47] Descriptions of Nature as ―fascinating" and interesting" indicated that a sense of curiosity and interest was aroused in students.

Table A4.3-15: Is Nature dangerous/destructive and frightening? Or is it peaceful? Is Nature hurtful or helpful?

Dangerous and frightening *(Negative)*	Wild animals (e.g., elephants, lions, wolves, snakes, and unassuming jungle creatures) (Shafia, Reza, Samuel, Yamina, Dan, Dyllan, Brian) and domestic animals (e.g., dogs) (Reza, Aaeesha); Insects (Shanon, Brian) (e.g., bees, spiders); Animal experimentation (e.g., scientists are experimenting with animals and therefore species can be combined to create new animals) (Brian); Natural disasters (e.g., tsunami, volcano, hurricane/tornado, earthquake, flood) (Aamir, Shafia, Shanon, Maya, Samuel, Gideon, Aaeesha, Dan, Dyllan, Victoria, Brian); Fires (Gideon, Dan, Victoria, Brian), stormy weather (e.g., hurricanes, lightning, thunder storm) (Aamir, Maya, Yamina), and being ―caught in a sandstorm" (Gideon)—although sand in itself (and beaches) are not scary parts of Nature (Gideon); Global warming is dangerous because it is destroying our planet (Shafia); Nature can be dangerous if you go too near to it, or if you are in a place at the wrong time (e.g., volcano, sharks, bumble bees) (Shanon).
Not dangerous *(Positive)*	Not scared of insects (Yamina) (e.g., grasshopper, praying mantis); We do not get earthquakes and tornadoes here in South Africa, so there‘s no need to fear them (Samuel); Plants and flowers are not dangerous (Gideon, Yamina)—unless they are poisonous (Reza, Yamina), but they ―can‘t move to us and prick us" (Reza); Nature is not dangerous as ―it can‘t come up to you and attack" you or break things of its own will (Reza); ―We can fall off mountains", so that is dangerous (Reza), but Nature is not going to cause intentional hurt (Victoria).
Nature is hurtful, Nature kills *(Negative)*	Animals: ―Lions...will eat us up" (Dyllan), ―rhinos...knock us over" and ―bees...sting us" (Brian); sometimes a lion kills another animal for no reason, except to be ―king of the jungle" (Dyllan); Plants: ―[W]hen we go on the mountain there‘s flowers pricking us and if we touch them...we‘re going to get sick" (Reza); Natural disasters: A tornado will ―[suck us] up" (Dyllan); tsunamis and volcanoes ―can wipe out five cities"—those things are ―bad" (Shanon).
Peaceful and relaxing *(Positive)*	Peaceful and relaxing (Gideon, Aaeesha, Dan); A place that ―makes [you] feel good" (Maya); Calming and mood-enhancing, by, for example, being surrounded by Nature and spending time alone in Nature, visiting natural places (e.g., the sea or a rainforest) and engaging in relaxing activities in Nature (e.g., fishing, having a quiet and private family picnic at Kirstenbosch Botanical Gardens (Shanon, Gideon, Raashid, Dan, Victoria).
Helpful, good *(Positive)*	Pure (e.g., ice) (Gideon), clean and fresh, and ―nutritious" (e.g., 100% pure fruit juice) (Yamina). Benevolent (e.g., providing shelter in a storm, warning animals of imminent danger) (Victoria); ―Nature can do good stuff" (Maya); ―It can help you lead a better life, it can help you change your point of view", and improve your mood—―[it] is there to enjoy it, and it is there to give you privileges and better things" (Shanon).
Dirty and evil *(Negative)*	Dirty (e.g., maggots in water, germs, dogs are forbidden) (Reza); Sometimes evil (e.g., vultures and hyenas that eat the leftovers of animals, lions are evil when they are trying to kill us) (Brian); Sometimes animals can appear helpful and caring and then they become harmful/destructive (Reza).

4. Status descriptions

The range of resource-oriented and conservationist views that the students described, were organised according to seven themes, namely, 1) Is Nature useful, and do we need it?, 2) How and why do we need to protect Nature?, 3) Is Nature over-used?, 4) Is Nature ruined?, 5) Do we need to be concerned about pollution in Nature?, 6) What impact does man have on the natural environment?, and, 7) Can Nature be repaired/restored?

Table A4.3-16: Is Nature useful? Do we need it?

Useful and needed *(Resource-oriented)*	In all the cases, Nature was viewed as something that is useful and necessary for people, for a variety of reasons and applications (Table 4.2); Nature was created for the purpose that we use it (Shafia, Aaeesha, Raashid, Victoria)—indeed, we should use and appreciate Nature more (Samuel); The use of Nature and natural resources is what has enabled people to advance in lifestyle (i.e., evolving from cavemen to modern day man) (Raashid, Brian).

Table A4.3-17: Specific examples of descriptions of Nature as useful and necessary

Illustration	Specific examples	Cases
Food and drink	Fruit, fruit juice, milk, porridge, milkshake, meat/animals/fish, eggs, honey from pollen, jam	Aamir, Shafia, Shanon, Maya, Samuel, Gideon, Yamina, Aaeesha, Raashid, Dyllan, Victoria, Brian
Water and ice	Rain	Aamir, Samuel, Gideon, Dan, Brian
Air or oxygen to breathe	From trees	Aamir, Shafia, Shanon, Maya, Yamina, Aaeesha, Raashid, Dan, Victoria, Brian
Fire		Gideon, Dan, Dyllan
Oil		Shafia, Raashid
Clothing	From sheep	Dan
Jewellery and luxuries	Diamonds	Aamir, Shanon, Aaeesha, Dyllan
Stationery	Paper	Yamina, Dyllan, Victoria
Glass, furniture, shelter and materials for building houses; and using Nature to put it into things that are man-made	A cave, bricks, granite sand, bed/table, wood from trees; Placing a plant or a fountain in our homes	Aamir, Reza, Shanon, Maya, Yamina, Raashid, Dan, Victoria); Shafia
Elephant dung		Victoria
Using wind for flight and as a form of natural temperature regulation		Gideon
Medicine or healing, and conducting animal experiments to find cures	Herbs and plants	Aamir, Shafia, Shanon, Aaeesha, Dan, Brian

Table A4.3-17 (cont.)

Illustration	Specific examples	Cases
For calming, relaxation and fun, sport, outings and hobbies, and pets	Soccer field, horse-riding, playing in my garden, hiking, swimming, walking, building sand castles	Shanon, Samuel, Gideon, Yamina, Raashid, Dan, Dyllan
Security and guide dogs		Dan
Religious artefacts		Dan
For survival and staying alive		Aamir, Shafia, Shanon, Gideon, Yamina, Aaeesha, Raashid, Victoria, Brian

Table A4.3-18: How and why do we need to protect Nature?

Reasons to protect Nature *(Conservationist)*	To keep Nature clean and quiet (Aaeesha); To prevent Nature from becoming destroyed or extinct (Raashid); We need Nature for our everyday use (Raashid) and for our survival (e.g., water) (Yamina, Victoria); There is a need to protect Nature in order to learn about it (Raashid), and there is a need to learn about Nature in order to be able to protect it (Samuel, Raashid).
Ways in which to protect Nature *(Conservationist)*	Nature parks (i.e., where plants cannot be removed) (Aamir); Not littering (Reza); “We need to do something...more than just recycling” (Victoria); “Only *Allah* can protect Nature” (Reza).

Table A4.3-19: Is Nature over-used?

Not over-used *(Resource-oriented)*	We look after Nature (Dyllan); We do not use everything in Nature (Reza, Yamina, Dan); We can re-plant (Aamir); Nature “can‘t really expire” (Victoria); “We have to use [Nature]” (Victoria).
Over-used *(Conservationist)*	Chopping down trees (Aamir); Over-fishing (Aaeesha), Killing animals for their tusks (Aaeesha); Using too much fuel (e.g., petrol, coal) (Shafia, Brian); Using too much water (Brian); Taking too many vegetables from the ground (Brian). Nature become over-used in recent years (Shafia); Over-using Nature destroys beautiful things (Maya); We are all to blame for using Nature too much (Shanon).

Table A4.3-20: Is Nature ruined?

Not ruined *(Resource-oriented)*	Nature is ―always clean and fresh" (Yamina); Nature is strong and it is not easily broken (Reza); There is always more that remains in Nature (Victoria).
Ruined *(Conservationist)*	Litter (Samuel, Dan); Air pollution (Samuel); The killing of animals (Dan); Deforestation (Maya, Dyllan); Damaged ozone layer (Maya) and melting ice caps (Shanon); Preventing the natural growth of trees and animals (Brian); ―Push[ing] Nature out of the way" in the development of land spaces (Maya, Victoria); Nature has become ruined in recent years (Shafia); It is alarming how rapidly people are ruining Nature (Gideon); ―One day...hopefully people will stop...ruining Nature" (Maya).
Partly ruined *(Resource-oriented & Conservationist)*	―Half of Nature is ruined [and] half is not" (Aamir); Nature in the sea is ruined, but ―Nature on the ground [land] isn't ruined" (Yamina).

Table A4.3-21: Do we need to be concerned about Nature?

Pollution *(Conservationist)*	Rubbish/litter (Reza, Samuel, Dan, Victoria); Water pollution: from birdlife and people (Reza), oil spills (Maya, Raashid), pollution in rivers that affects the fish (Yamina, Aaeesha, Raashid, Dan); Air pollution: car fumes and factories (Maya, Gideon, Samuel, Victoria), the damaged ozone layer (Samuel, Gideon, Raashid, Dan, Victoria), and issues related to global warming (Samuel, Gideon), such as melting ice caps and more frequent fires (Gideon); People need to take pollution seriously (Shanon); ―There's no point in learning about Nature and not doing anything to stop polluting" (Samuel).
Endangered, running out *(Conservationist)*	Plants (Aamir); Fuel (Shafia); One day we will only have technology as there will be no Nature left (Dan).
People kill, Nature is becoming extinct *(Conservationist)*	People kill animals in Nature, and therefore some species are becoming extinct, for example, lions (Brian), deer (Brian), and silver gorillas (Raashid).
The end of the natural world *(Conservationist)*	As a result of the damage being done to the natural environment, ―[h]umanity might die out" (Victoria); If people continue polluting Nature and using it too much, eventually there will be nothing left on the planet (Shafia, Maya, Dan, Brian).—and then, one day, we will need to ―find a new planet to live on" (Brian).

Table A4.3-22: What impact do people have on the natural environment?

Negative impact *(Conservationist)*	Air pollution (Brian) and the hole in the ozone layer (Shafia, Maya); Global warming (Shafia, Brian), melting ice caps, rising sea levels, changing weather patterns (Shafia) and polar bears dying (Shafia, Maya); The destruction of habitats and ecosystems (Dyllan); ―Some people do wrong stuff" (e.g., with natural resources) (Aaeesha).
Positive impact *(Conservationist)*	―Some people [are] trying to destroy Nature, but....some other people...will try and help Nature" (Yamina).

Table A4.3-23: Can nature be repaired/restored?

Can be restored *(Resource-oriented)*	Nature repairs itself / “cleanses itself” (Samuel, Victoria); Nature re-grows (Maya, Gideon); We can re-plant (Shafia, Yamina, Raashid, Victoria, Brian); We “can repair Nature manually with scientific things”, although this is unnatural (e.g., breeding animals) (Shanon); Nature can only be repaired over time (Shanon, Raashid) (e.g., it takes many years for the Earth to replenish the oil that has been pumped from underground).
Cannot be repaired *(Conservationist)*	Some damage cannot be fixed (Aaeesha); Trees (and branches) do not grow back (Dan, Dyllan, Victoria); Animal species that have been killed (Maya, Gideon, Dan, Dyllan) and which have become extinct (Aaeesha) cannot live again; The damaged ozone layer and (Dhafia, Gideon) global warming (Shafia) cannot be repaired; The aftermath of a volcano or flood (Gideon), and a damaged mountain, cannot be repaired—“until *[Allah]* wants it to be repaired” (Reza).

Appendix 4.4
EXAMPLES OF CASES LOCATED AT VARIOUS POSITIONS ON THE KNOWABLE-UNKNOWABLE CONTINUUM, INCLUDING SUPPORTING CONTENTS EXTRACTED FROM THE STUDENTS' STATEMENTS ABOUT NATURE

The students' epistemological worldview descriptions ranged from strongly Knowable (K++) to strongly Unknowable (U++), and therefore cases were located at various positions on the Knowable-Unknowable continuum, for example (Figure A4.4-1):

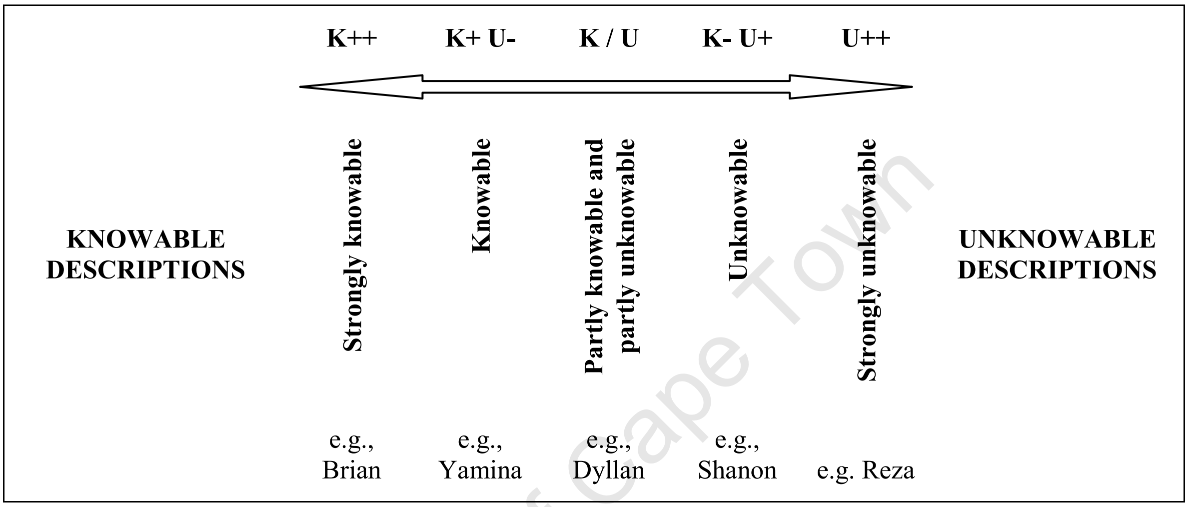


Figure A4.4-1: Overview of illustrative cases located at each of the various positions on the Knowable-Unknowable continuum

EXAMPLES OF CASES

Yamina held a knowable (K+U-) view of the natural world (Figure A4.4-2):

Synopsis of Knowable responses:	K++	K+ U-	K / U	K- U+	U++	Synopsis of Unknowable responses:
Nature is understandable Nature is not confusing or complicated, and it is not mysterious Nature is orderly and things grow in cycles We can find everything in nature and see and touch it, and so we are able to understand it more Anybody can see and learn things about nature We learn things about nature in Natural Science at school	Strongly Knowable	Knowable	Partly Knowable and partly Unknowable	Unknowable	Strongly Unknowable	Nature is a mixture of different things in different places There are some things we don't know about nature (e.g., the purpose of certain natural events) Nature is unpredictable

Figure A4.4-2: Overview of the contents of Yamina's epistemological worldview statements

Dyllan's view of the natural world was partly knowable and partly unknowable (K/U) (Figure A4.4-3):

Synopsis of Knowable responses:	**K++**	**K+ U-**	**K / U**	**K- U+**	**U++**	**Synopsis of Unknowable responses:**
You can tell what's going to happen in the future There is some order in nature, like a cycle We can understand nature if we learn about it We can find out things about nature and experience it We get used to things in nature and then they're not mysterious	**Strongly Knowable**	**Knowable**	**Partly Knowable and partly Unknowable**	**Unknowable**	**Strongly Unknowable**	If we haven't learnt about something in nature is confusing There are some things we don't know For some things there is no real answer and we don't understand them Some things cannot be explained There are different and strange things in nature Nature is not simple and ordinary Nature is complicated and it changes Scientists can make mistakes

Partly knowable and partly unknowable response

If there was too much that is confusing then science would be quite short because we wouldn't have a lot to talk about, so nature is equally understandable and confusing.

Figure A4.4-3: Overview of the contents of Dyllan's epistemological worldview statements

Shanon held an unknowable view (K– U+) of the natural world (Figure A4.4-4):

Synopsis of Knowable responses:	**K++**	**K+ U-**	**K / U**	**K- U+**	**U++**	**Synopsis of Unknowable responses:**
Everything has a reason in nature We can learn more about nature and understand it better Zoologists, botanists, biologists, and environmentalists study nature	**Strongly Knowable**	**Knowable**	**Partly Knowable and partly Unknowable**	**Unknowable**	**Strongly Unknowable**	We can't always figure out the reason for things in nature Nature is complicated and confusing, and there are things we don't understand properly Nature changes Nature is unpredictable There will always be more to learn more about nature

Figure A4.4-4: Overview of the contents of Shanon's epistemological worldview statements

Reza held a strongly unknowable (U++) view of the natural world (Figure A4.4-5):

Synopsis of Knowable responses:	**K++**	**K+ U-**	**K / U**	**K- U+**	**U++**	**Synopsis of Unknowable responses:**
We need to study nature so that we can have more knowledge about it	**Strongly Knowable**	**Knowable**	**Partly Knowable and partly Unknowable**	**Unknowable**	**Strongly Unknowable**	Nature is complicated, diverse, and not orderly Nature is confusing There are mysteries in nature and things that have not been discovered Everybody has a question about nature Nature is unpredictable It requires hard work for a long time in order to find everything in nature

Figure A4.4-5: Overview of the contents of Reza's epistemological worldview statements

Appendix 4.5
EXAMPLES OF CASES LOCATED AT VARIOUS POSITIONS ON THE NATURALISTIC—SUPER-NATURALISTIC CONTINUUM, INCLUDING SUPPORTING CONTENTS EXTRACTED FROM THE STUDENTS' STATEMENTS ABOUT NATURE

The students' ontological worldview descriptions ranged from strongly Naturalistic (N++) to strongly Super-naturalistic (S++), and therefore cases were located at various positions on the Naturalistic-Super-naturalistic continuum, for example (Figure A4.5-1):

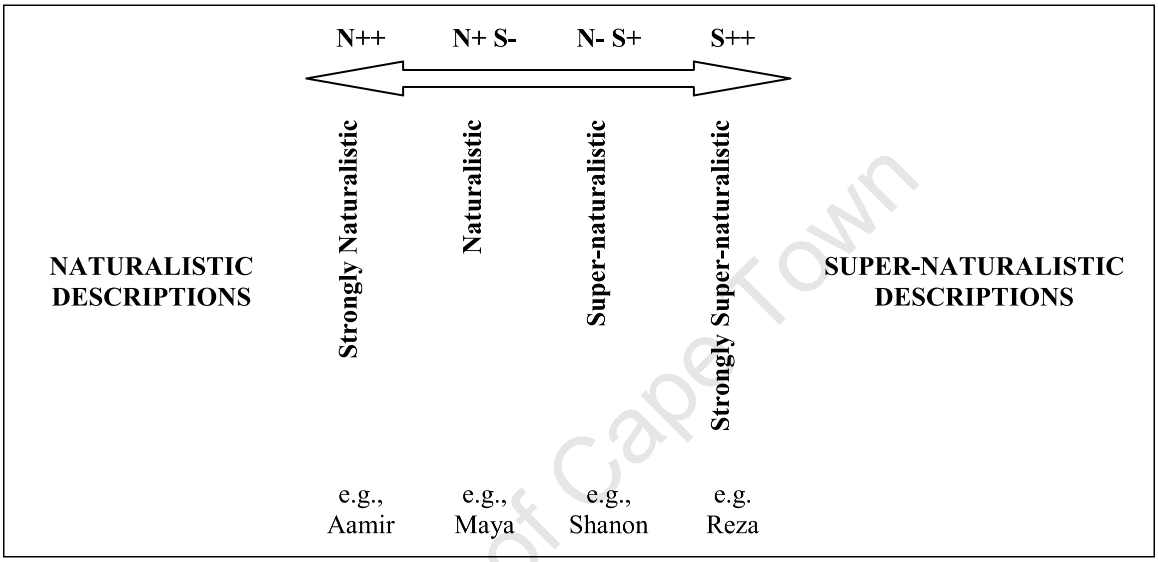


Figure A4.5-1: Overview of illustrative cases located at each of the various positions on the Knowable-Unknowable continuum

EXAMPLES OF CASES

Maya held a naturalistic view (N+ S-) of the natural world (Figure A4.5-2):

Synopsis of Naturalistic responses:	**N++**	**N+ S-**	**N- S+**	**S++**	**Synopsis of Super-naturalistic responses:**
[After creation]…but now it is doing its own thing Not holy (only *Hashem* is holy) Things happen naturally (e.g., tsunamis and earthquakes cause floods) There's always something to make something happen in nature (e.g., rain, cycle of seasons)	**Strongly Naturalistic**	**Naturalistic**	**Super-naturalistic**	**Strongly Super-naturalistic**	God created nature… It is spiritual because *Hashem* created it

Figure A4.5-2: Overview of the contents of Maya's ontological worldview statements

Shanon held a super-naturalistic (N– S+) view of the natural world (Figure A4.5-3):

Synopsis of Naturalistic responses:	N++	N+ S-	N- S+	S++	Synopsis of Super-naturalistic responses:
You can‘t see air and tiny molecules Mountains are formed by minerals over time, weather changes caused certain animals to become extinct, tsunami waves just have to spread out somewhere	**Strongly Naturalistic**	**Naturalistic**	**Super-naturalistic**	**Strongly Super-naturalistic**	God created nature Nature is spiritual because of enjoying it, it is beautiful, it can help you to lead a better life, and calm you down and improve your mood Tsunamis and volcanoes happen for a purpose, linked to spirituality

Figure A4.5-3: Overview of the contents of Shanon‘s ontological worldview statements

Reza held a **strongly super-naturalistic** view (S++) of the natural world (Figure A4.5-4):

Synopsis of Naturalistic responses:	N++	N+ S-	N- S+	S++	Synopsis of Super-naturalistic responses:
Nature is not holy like the Q‘uran	**Strongly Naturalistic**	**Naturalistic**	**Super-naturalistic**	**Strongly Super-naturalistic**	God made nature God controls everything Only God can protect and repair nature Without God, things can‘t happen in nature Heaven and hell, devil, ghosts, Day of Judgment Forbidden to touch dogs (they are dirty, requires ritual washing afterwards)

Figure A4.5-4: Overview of the contents of Reza‘s ontological worldview statements

Appendix 4.6
EXAMPLES OF CASES LOCATED AT VARIOUS POSITIONS ON THE POSITIVE-NEGATIVE CONTINUUM, INCLUDING SUPPORTING CONTENTS EXTRACTED FROM THE STUDENTS' STATEMENTS ABOUT NATURE

The students' emotional worldview descriptions ranged from strongly Positive (Pos++) to strongly Negative (Neg++), and therefore cases were located at various positions on the Positive-Negative continuum, for example (Figure A4.6-1):

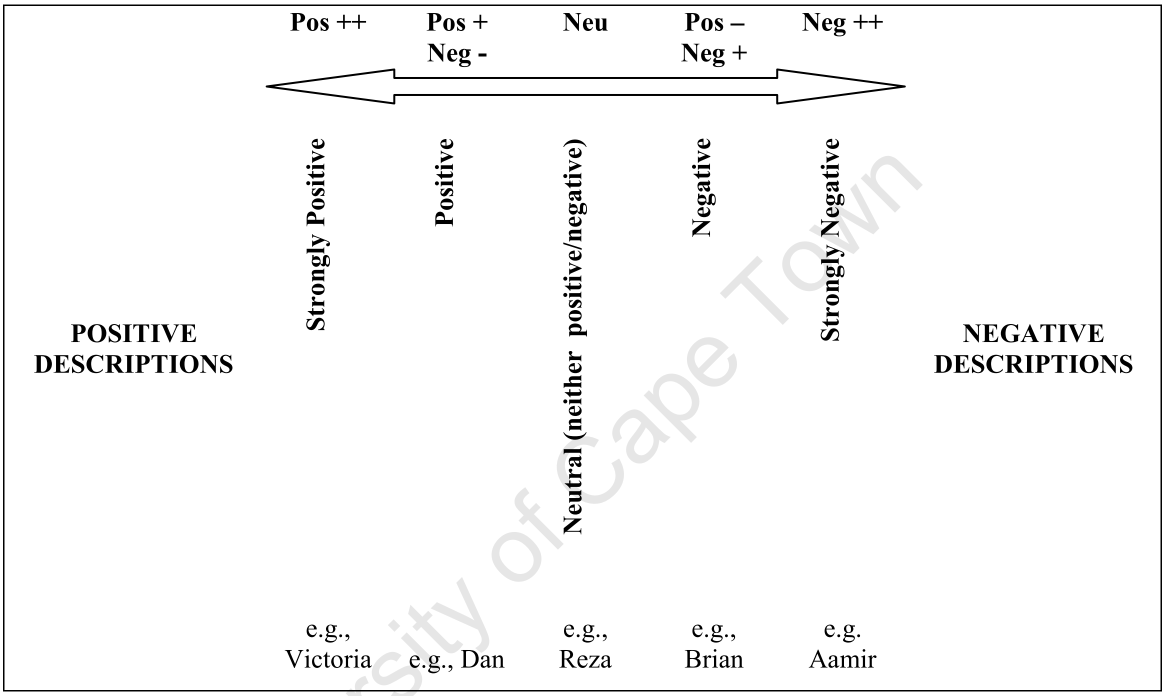


Figure A4.6-1: Overview of illustrative cases located at each of the various positions on the Knowable-Unknowable continuum

EXAMPLES OF CASES

Dan held a positive view of the natural world (Figure A4.6-2):

Synopsis of Positive responses:	**Pos ++**	**Pos + Neg -**	**Neu**	**Pos – Neg +**	**Neg ++**	**Synopsis of Negative Responses:**
There are beautiful things in nature It is nice and I enjoy it, it is fun I feel sad when an animal dies Nature is quiet and calm, private, you can sit and relax in nature Nature is fascinating and interesting Nature is not ordinary, not just there—you have to go to nature, not something you see everyday	**Strongly Positive**	**Positive**	**Neutral (neither positive/negative)**	**Negative**	**Strongly Negative**	Nature is dangerous and frightening (e.g., tornado, volcano, flood, fire, elephant charging you)
Synopsis of Neutral responses: None						

Figure A4.6-2: Overview of the contents of Dan's emotional worldview statements

Reza held a neutral view of the natural world (Figure A4.6-3):

Synopsis of Positive responses:	**Pos ++**	**Pos + Neg -**	**Neu**	**Pos – Neg +**	**Neg ++**	**Synopsis of Negative responses:**
I enjoy nature Things are beautiful in nature we enjoy ourselves in everyday life because of nature I enjoy the colours of the sea water Without nature, the world would look dull	**Strongly Positive**	**Positive**	**Neutral (neither positive/negative)**	**Negative**	**Strongly Negative**	Flowers that prick us Nature is dangerous and frightening Nature is dirty, dogs are forbidden

Synopsis of Neutral responses:

Nature is not frightening

Figure A4.6-3: Overview of the contents of Reza‘s emotional worldview statements

Brian held a negative view of the natural world (Figure A4.6-4):

Synopsis of Positive responses:	**Pos ++**	**Pos + Neg -**	**Neu**	**Pos – Neg +**	**Neg ++**	**Synopsis of Negative responses:**
Nature is interesting I enjoy eating fruit and experiencing nature, I enjoy taking photos at Kruger National Park	**Strongly Positive**	**Positive**	**Neutral (neither positive/negative)**	**Negative**	**Strongly Negative**	Nature is dangerous and destructive Nature is scary We get hurt by things in nature Sometimes nature can be evil when animals are trying to kill us

Synopsis of Neutral responses:

We see lots of everything in nature so it is ordinary

Figure A4.6-4: Overview of the contents of Brian‘s emotional worldview statements

Aamir held a strongly negative view of the natural world (Figure A4.6-5):

Synopsis of Positive responses:	**Pos ++**	**Pos + Neg -**	**Neu**	**Pos – Neg +**	**Neg ++**	**Synopsis of Negative responses:**
None	**Strongly Positive**	**Positive**	**Neutral (neither positive/negative)**	**Negative**	**Strongly Negative**	I don‘t like nature because it is too ―girlie” Nature is too colourful Nature is boring because you see the same thing every day I get scared Nature is dangerous and it can kill you Nature is frightening
Synopsis of Neutral responses: None						

Figure A4.6-5: Overview of the contents of Aamir‘s emotional worldview statements

Appendix 4.7
EXAMPLES OF CASES LOCATED AT VARIOUS POSITIONS ON THE RESOURCE-ORIENTED—CONSERVATIONIST CONTINUUM, INCLUDING SUPPORTING CONTENTS EXTRACTED FROM THE STUDENTS' STATEMENTS ABOUT NATURE

The students‘ ontological worldview descriptions ranged from strongly Resource-oriented (R++) to strongly Conservationist (R++), and therefore cases were located at various positions on the Resource-oriented—Conservationist continuum, for example (Figure A4.7-1):

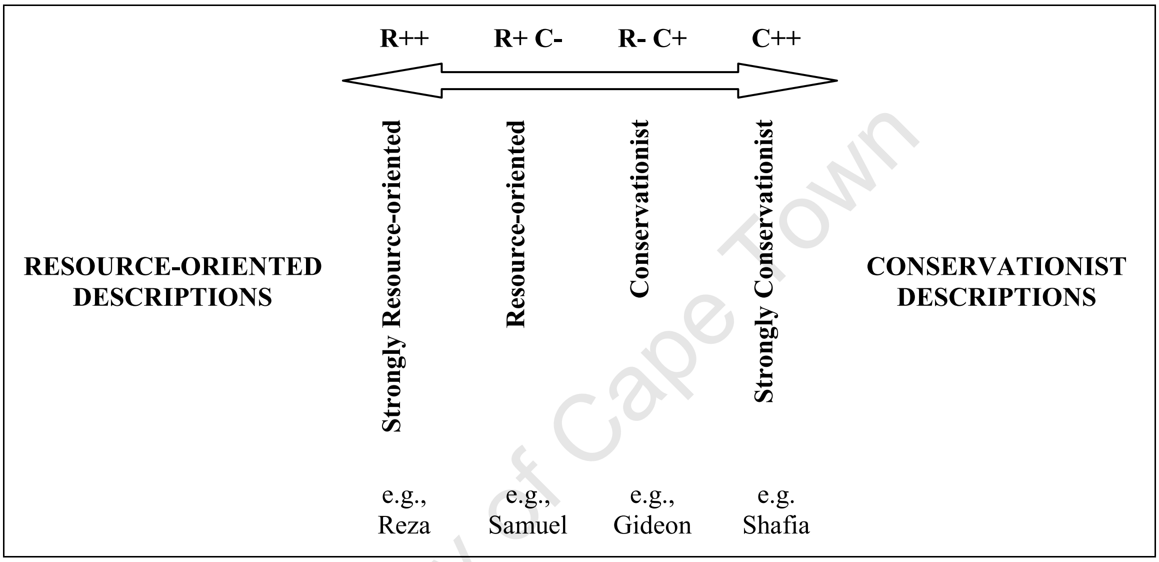


Figure A4.7-1: Overview of illustrative cases located at each of the various positions on the Resource-oriented—Conservationist continuum

EXAMPLES OF CASES

Samuel held a resource-oriented view (R+ C-) of the natural world (Figure A4.7-2):

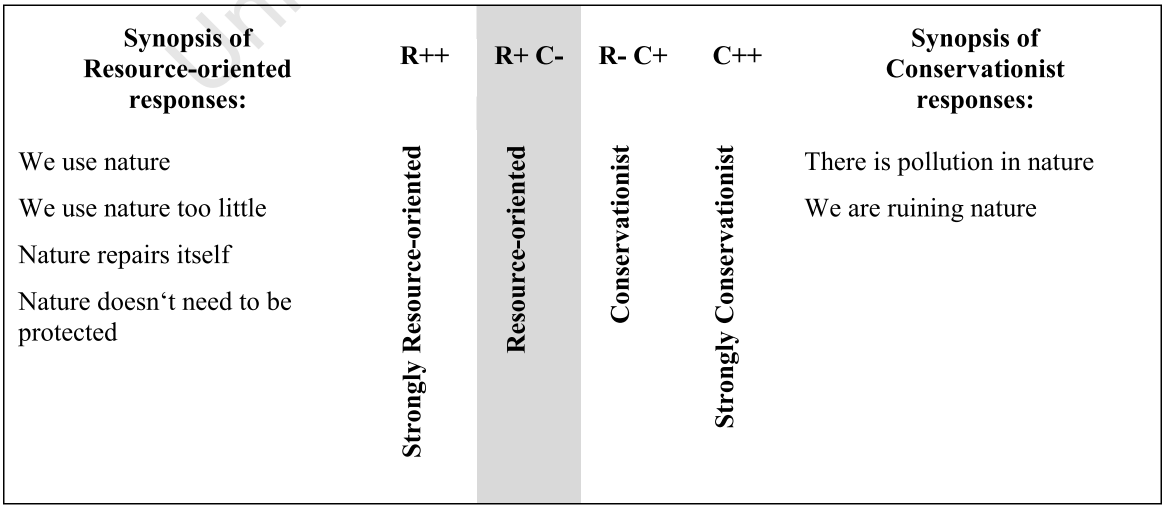


Figure A4.7-2: Overview of the contents of Samuel‘s status worldview statements

Gideon held a conservationist view (R– C+) of the natural world (Figure A4.7-3):

Synopsis of Resource-oriented responses:	**R++**	**R+ C-**	**R- C+**	**C++**	**Synopsis of Conservationist responses:**
We use nature We need nature Nature is not over-used Nature repairs itself	**Strongly Resource-oriented**	**Resource-oriented**	**Conservationist**	**Strongly Conservationist**	Nature is polluted and damaged Nature is ruined Nature cannot be repaired We need to protect nature

Figure A4.7-3: Overview of the contents of Gideon‘s status worldview statements

Shafia held a strongly conservationist view (C++) of the natural world (Figure A4.7-4):

Synopsis of Resource-oriented responses:	**R++**	**R+ C-**	**R- C+**	**C++**	**Synopsis of Conservationist responses:**
We use nature, and we put nature into man-made things We need nature	**Strongly Resource-oriented**	**Resource-oriented**	**Conservationist**	**Strongly Conservationist**	Nature is ruined Nature is running out Nature cannot be repaired Man‘s negative impact We need to conserve and protect nature

Figure A4.7-4: Overview of the contents of Shafia‘s status worldview statements

Appendix 4.8
SYNOPSES OF WORLDVIEW PROFILES OF THE REMAINING CASES (ARRANGED ALPHABETICALLY BY NAME)

AAEESHA – Muslim girl

- Some of nature is complicated and we don‘t know about it, but we can know most things and we keep on learning things about nature
- God created nature and He sends down natural disasters in response to disobedient people; but some things happen for physical reasons
- I enjoy nature and for me it is beautiful, peaceful and interesting
- We really need nature and we use it a lot, but some things are over-used and damaged.

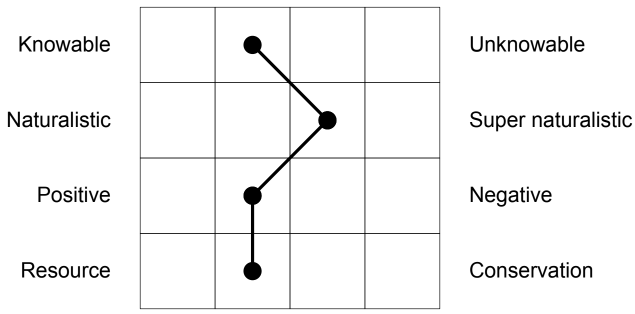


Figure A4.8-1: Synopsis of Aaeesha‘s worldview profile

AAMIR – Muslim boy

- Nature is complex and complicated but you can understand it if you work hard enough—we need to pass in the legacy of knowledge when people die
- God made the Earth, but nature is not holy/spiritual, and events happen due to naturalistic causes
- I don‘t like nature because it is too —grlie” and it is monotonous and dangerous
- We need things from nature—that‘s their purpose—and nature won‘t run out

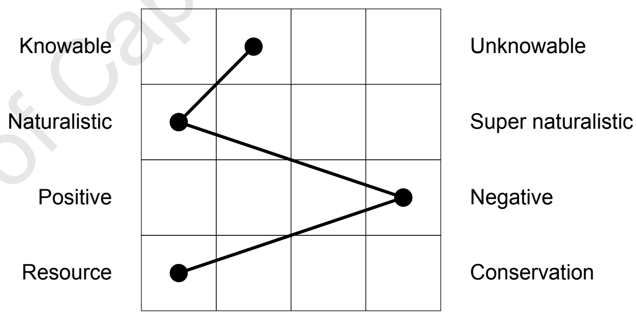


Figure A4.8-2: Synopsis of Aamir‘s worldview profile

BRIAN - Christian boy

- Nature is understandable and you know what‘s going to happen
- Nature doesn‘t have its own thoughts, and events don‘t have a purpose; I‘d rather believe in God than in whatever scientists‘ answers are
- Besides being beautiful, nature can sometimes be frightening and dangerous/harmful
- We need nature, but we keep on taking too much, so we are killing nature.

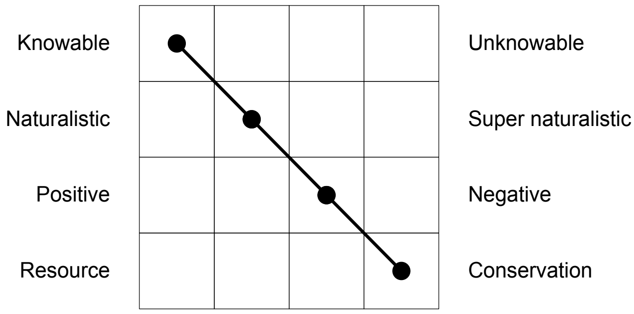


Figure A4.8-3: Synopsis of Brian‘s worldview profile

DAN – Jewish boy

- Nature is orderly, but we can‘t predict natural disasters
- Nature is mostly understandable and it should be studied, although a person might miss something
- God created nature, but events are due to naturalistic causes and for physical purposes
- Nature is not ordinary; it is beautiful and fascinating
- Nature is useful and we need it, but pollution is a worry.

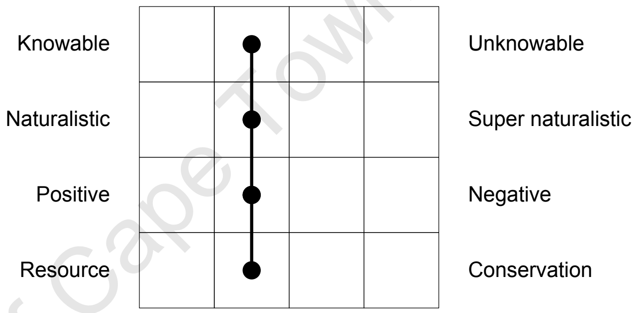


Figure A4.8-4: Synopsis of Dan‘s worldview profile

DYLLAN - Christian boy

- There are things in nature that I don‘t know and which are confusing, but once you‘ve learnt about it we can understand parts of it—that‘s why we have science
- Nature has no beginning or end—I don‘t trust what scientists tell us as they make mistakes—I rather believe God
- Nature is fascinating, but it is also powerful and dangerous
- We need nature for everyday life, but it cannot be repaired so it should be used sustainably

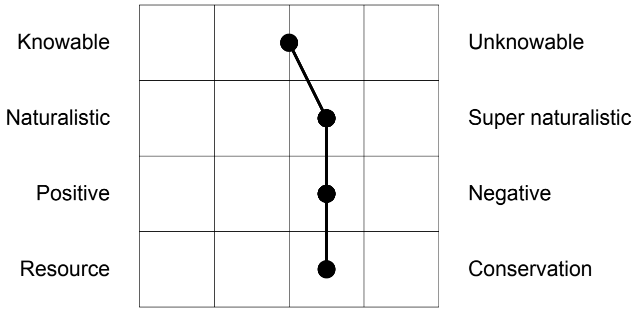


Figure A4.8-5: Synopsis of Dyllan‘s worldview profile

GIDEON – Jewish boy

- Nature is complicated and unpredictable and there are lots of things we don‘t yet know or understand
- It is possible that nature was created by God, but now it‘s controlled by itself—there are many things in the Jewish Torah that I don‘t understand about nature, and I‘m starting to believe in karma
- Nature is calming and beautiful, mostly not that dangerous
- We need nature to survive, but it‘s becoming quite damaged from pollution

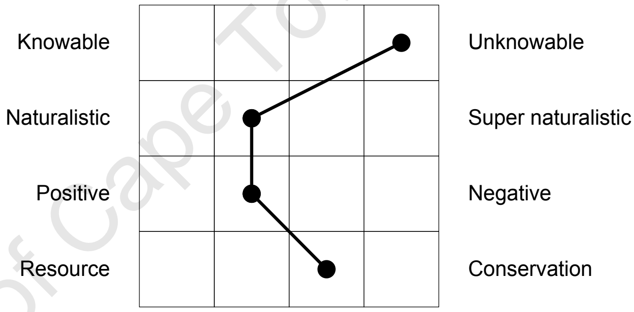


Figure A4.8-6: Synopsis of Gideon‘s worldview profile

RAASHID – Muslim boy

- There is lots we don‘t know, but everything links up as part of a cycle
- God created everything for a purpose
- Nature is enjoyable
- We make things from natural resources/materials; we should protect it so that there‘s enough for us to use

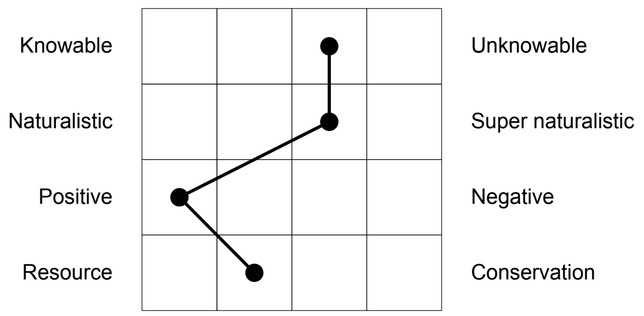


Figure A4.8-7: Synopsis of Raashid‘s worldview profile

REZA – Muslim boy

- Nature is complicated and confusing and it requires a lot of hard work and searching to find out things—we want to answer our questions about nature
- God created nature and He controls what happens if He wants it, and only He knows what will happen in the future
- Nature is beautiful because God created it and it can sometimes be impure and dangerous, but it‘s not too frightening and it doesn‘t set out to harm us
- We need nature and we use it a lot, but it won‘t run out—anyway, nature can only be protected by Allah.

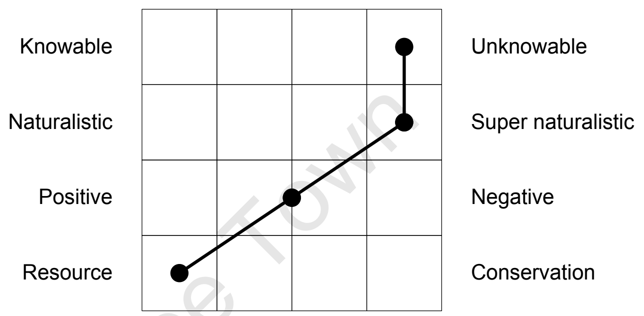


Figure A4.8-8: Synopsis of Reza‘s worldview profile

SAMUEL – Jewish boy

- Although there‘s a lot that is complicated and mysterious in nature, we can understand most of it, and there‘s no point living in a world we don‘t know
- God must have created nature, but things happen by physical causes and reasons
- Although some of nature is dangerous, it is beautiful and enjoyable for everyone, and I find it fascinating—people should appreciate it more
- We use nature everyday and we need it to live, but pollution is ruining the environment—we should use nature more and spend time outside rather than with technology.

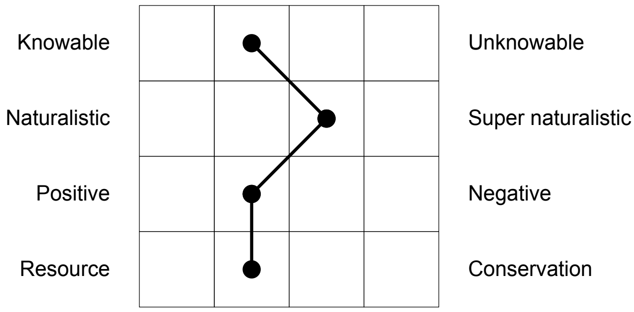


Figure A4.8-9: Synopsis of Samuel‘s worldview profile

SHAFIA – Muslim girl

- Nature is complicated and confusing – we can find out some things but it takes a long time, and there are some things that we cannot understand.
- Allah created nature, but scientists say there was a Big Bang – the scientists could be right and we (my religion) could be right.
- There are some dangerous and destructive elements to nature, but for me it is a happy, enjoyable and interesting place to be.
- Allah created nature for us to use, but we are ruining it and causing global warming.

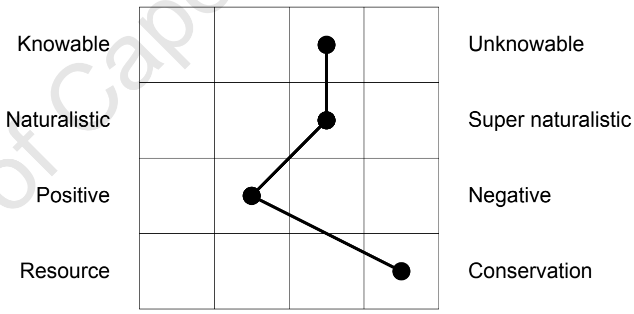


Figure A4.8-10: Synopsis of Shafia‘s worldview profile

SHANON – Jewish girl

- Nature is complicated and it changes, and it is unpredictable—we will always be learning more about it
- There are different theories (e.g., how the Earth was formed)—she can't choose between religion and science
- Nature is formed by different things over time, but God created the world and things that happen in nature are God's response to people being bad/good—although she's not sure that she believes that—nature is just doing its job (e.g., tsunami)
- Nature is not malevolent—it is beautiful and enjoyable
- People need nature to make things, but it is becoming polluted and over-used

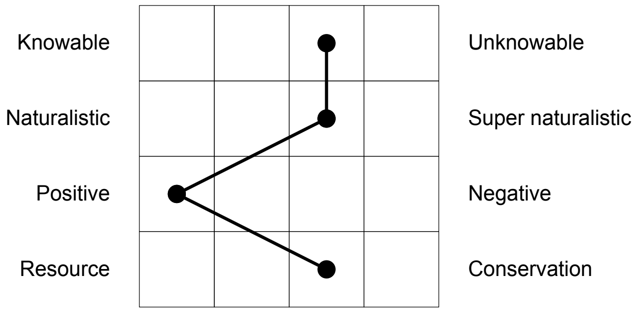


Figure A4.8-11: Synopsis of Shanon's worldview profile

VICTORIA - Christian girl

- Nature is unpredictable but things happen for a reason and things happen in certain ways; it is understandable
- God created the Earth with the Big Bang and then started evolution; nature is a psychological being with its own feelings and it has its own power to change things and it finds its own way to help you
- Nature is fascinating and enjoyable, not dangerous or malicious
- We need nature and it was created for the purpose that we use it—you cannot destroy nature itself

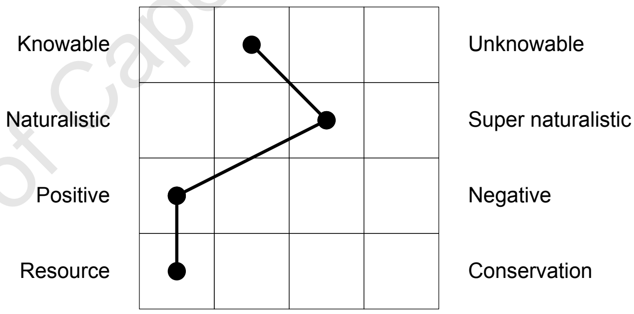


Figure A4.8-12: Synopsis of Victoria's worldview profile

Appendix 4.9
EVIDENCE OF ISSUES ARISING FROM COHERENT LINKS WITH NAIVE NOS VIEWS AND INCOHERENT LINKS WITH INFORMED NOS VIEWS

The data here are organised according to the five NOS aspects, and first concerning coherent links with naive NOS views and then incoherent links with informed NOS views. Each figure comprises a statement that summarises the contents of the link at the top (summary statement), as well as extracts from the child‘s NOS responses on the left-hand-side (NOS) and worldview responses on the right-hand-side (Nature). The coherence principle applied to each link is provided at the bottom (coherence principle). Particular issues emerging from each link are indicated in a callout shape.

1. TENTATIVE, SUBJECT TO CHANGE:

Incoherent links with informed NOS views

SUMMARY STATEMENT

I don‘t think Nature has to be studied, but scientists help us find out more about our planet and work out ways to improve our lives. (Invent & develop) (Gideon)

NOS	NATURE
They work out ways to help make our lives better and help us find out more about our planet.	We could learn more about Nature, but I don‘t think it‘s something that has to be studied.

If Nature can be studied, does it need to be studied?

COHERENCE PRINCIPLE
Contradiction

Figure A4.9-1: Incoherent link between informed NOS view and Knowable statement about Nature, relating to the theme *Invent and develop*

SUMMARY STATEMENT

In twenty millions years‘ time the sun‘s going to burn out and we‘re all going to die of frost, but even if they tell us this now, I think there‘s a good chance it could change in the future. (Change) (Gideon)

NOS	NATURE
…I think that even if they tell us stuff now, I think there‘s a very good chance of it being different in the future…I think that everything has to change eventually...so I think even if they tell us stuff now, I think it‘s possible that could change in the future…	…In twenty million years the sun‘s going to burn out and we‘re all going to die of frost. Apparently, the sun in about 20 million years is just going to turn back into a shining star…apparently it‘s just going to burn out!

Perhaps not wanting to accept predictions of negative events in Nature.

COHERENCE PRINCIPLE
Competition

Figure A4.9-2: Incoherent link between informed NOS view and Negative statement about Nature, relating to the theme *Change*

SUMMARY STATEMENT

Scientists help us find out about our planet, but I'm not sure if things happen for a purpose in Nature (e.g., karma) or by Nature itself doing things (i.e., those things are beyond what scientists can find out). (Science vs. religion) (Gideon)

NOS

…[Scientists] help us find out more about our planet.

How do we make sense of alternative knowledge about the natural world, that is, other than science (i.e., cultural/religious beliefs)?

NATURE

I'm not sure if things happen in Nature for a purpose. I don't really believe in that but I think it is possible that it does happen. Because there are cultures in which people believe that stuff does happen for a reason. Like karma, for instance (e.g., bully & car accident)…Now the questions is, is that or is that not Nature doing something?

COHERENCE PRINCIPLE

Contradiction

Figure A4.9-3: Incoherent link between informed NOS view and Super-naturalistic statement about Nature, relating to the theme *Science vs. religion*

2. EMPIRICAL EVIDENCE:

2.1. Coherent links with naive NOS views

SUMMARY STATEMENT

Science is electricity and experiments: it's mostly using it or making something (e.g., invent an electrical fence, assemble a motor, design new machines), and in the future there's going to be mainly technology and people won't think so much of Nature. (Invent & develop) (Dan)

NOS

Because sometimes scientists haven't done something and then they can give you the wrong advice, e.g., Invent an electrical fence: They might tell you what to use to make it before they've checked it is right and it's actually wrong.

Science is electricity and fluids so you don't need facts to do science. There are some facts with electricity but it's mostly using it or making something.

…With plugs and maybe they want to make something with a motor in that moves. [In order to know what to do] they just experiment. They just, like, put a motor together and they think maybe you join this wire to that wire…

Opinions are part of science because they are part of an invention which could be successful (e.g., a car that's now on the road) or it could fail.

NATURE

…Nature will run out some day. In the future there's only gonna be- there's mainly gonna be technology and people won't think so much of Nature. They'll only think about technology in their modern day lives.

What work do scientists do? Do scientists only work with and develop technological things?

COHERENCE PRINCIPLE

Explanation

Figure A4.9-4: Coherent link between naive NOS view and Conservationist statement about Nature, relating to the theme *Invent and develop*

SUMMARY STATEMENT

Science is based on what they tell us, e.g., Venus/eclipse. (Find out & learn) (Dylan)

NOS

It is based on what they tell us.

When scientists tell us things and publish things, how do they know such things?

NATURE

…People say that in 2012 there‗ll be another eclipse where Venus will come over the sun. They say the next time that will happen is like in the thousands of years‗ time…

COHERENCE PRINCIPLE

Explanation

Figure A4.9-5: Coherent link between naive NOS view and Knowable worldview statement, relating to the theme *Find out and learn*

SUMMARY STATEMENT

I‗m not sure if scientists work with space because we can‗t touch planets; some of Nature we can‗t see and touch. (Unknown) (Dylan)

NOS

…But I‗m not too sure if they also- ‗cos I know, like, space is Nature because it always was there, but they don‗t really study- they don‗t work with that, m‗am, because they can‗t touch the planets…

Do scientists also work with intangible and invisible parts of the natural world?

NATURE

And there is more to Nature than what we can see and touch, because, if you just see a tree as its full growth, we wouldn‗t know that it was this small and then grow and grow and grow, and that it needed water to get as big as it is at full growth.

COHERENCE PRINCIPLE

Explanation

Figure A4.9-6: Coherent link between naive NOS view and Unknowable statement about Nature, relating to the theme *Unknown*

SUMMARY STATEMENT

We find out things from experiencing it ourselves. (Search, explore, observe) (Dylan)

NOS

…Voyager 1 that was sent out so they can experience our solar system, Mr. [B] says it‗s only gone passed Pluto now…And that it‗s shut down because it works off solar power and now it‗s not getting any sun because it‗s past Pluto. So, maybe it‗s not past Pluto. I don‗t know, M‗am. It‗s strange. Or maybe, as they passed Pluto another sun came so it was still on…it‗s quite confusing!

NATURE

We can find out things about Nature from the Internet, and books, and we can experience it ourselves, like by going to the jungle or somewhere. Or maybe people experienced a volcano erupting…

Although scientific knowledge is derived from direct experiences, how accurate/reliable is that knowledge, or do scientists sometimes make mistakes?

COHERENCE PRINCIPLE

Explanation

Figure A4.9-7: Coherent link between naive NOS view and Knowable statement about Nature, relating to the theme *Search, explore, observe*

2.2. Incoherent links with informed NOS views

SUMMARY STATEMENT

In Nature, you can't predict the weather, yet scientists use satellites in space to make weather predictions. (Predicting Nature) (Victoria)

NOS

[To predict the weather] they look at pictures of the earth from satellites in space.

NATURE

You can't always predict what will happen in Nature, like sometimes with the weather there are clouds coming, but yet it still doesn't rain.

Is Nature predictable?
Can scientists predict Nature?

COHERENCE PRINCIPLE

Contradiction

Figure A4.9-8: Incoherent link between informed NOS view and Unknowable statement about Nature, relating to the theme *Predicting Nature*

SUMMARY STATEMENT

Scientists dig deep (e.g., archaeologists/dinosaur bones), or they look deep into space, discover medicinal plants, observe the stars and use a telescope or satellite pictures, but I'm not sure how they find out things. (Search, explore, observe) (Brian)

NOS

It depends on what sort of science…They discover history (i.e., archaeologists) or look deep into space (i.e., planets), try new inventions (i.e., robots), try new experiments (i.e., medicine), and find cures for illnesses.

Scientists work anywhere…e.g., Lower ground or dry land to search or dig deeper; medicine: in the jungle—Nature could give you some things from plants; inventions: secret place—no-one knows where they are; for space: higher section, like high hills, high mountains, to see the stars.

To see if there are other planets, they look through a large telescope.

Archaeologists look for remains of dead dinosaurs under the surface; [experiments]: I saw it on TV—they mix them to see what's the reaction.

Scientists know how dinosaurs looked like because the shape of the bones when all the parts are put together and it depends on the size of the jaw and how sharp the teeth are.

The satellites in space take pictures of earth so scientists have an idea of what the weather will be like for the next few days.

NATURE

Scientists have discovered Nature and studied it and they've been telling us, so that's how we know things, although I don't know exactly how they find out things.

How exactly do scientists go about their work and develop knowledge about the natural world?

COHERENCE PRINCIPLE

Competition

Figure A4.9-9: Incoherent link between informed NOS view and Knowable statement about Nature, relating to the theme *Search, explore, observe*

SUMMARY STATEMENT

Scientists help everyone to understand the world better, yet it is unnecessary to learn more about Nature. (Find out & Learn) (Victoria)

NOS

[Scientists] study Nature.
There are all different types of scientists, like archeologists (they dig), biologists (look at the environment), geographers (look at the world and cities), and meteorologists (they study more of the weather)…
[Scientists do their work] to help everyone understand the world better.

NATURE

…But we don't really need to study nature or to learn more about it, otherwise it might just take away the lust to be in nature. It's nice to have some mysteries unsolved just to keep it fascinating. Nature is mysterious, like, how does the ice stay ice even though the sun comes down on it?...It is mysterious even though we are used to it.

Why do we need to understand more about the natural world?
How does an increased understanding of the natural world affect our enjoyment and appreciation of Nature?

COHERENCE PRINCIPLE
Contradiction

Figure A4.9-10: Incoherent link between informed NOS view and Unknowable and Positive statement about Nature, relating to the theme *Find out and learn*

SUMMARY STATEMENT

Scientists study plants, animals, etc, but anybody just sees things in Nature and finds out (i.e., studying Nature is not specialist work done only by scientists, but by anyone). (Find out & learn) (Yamina)

NOS

Different scientists do different work…They study different things…e.g. It is mostly studying plants and animals. Maybe they study fossils as well….and humans.

NATURE

Anybody just sees and finds out.

If the natural world is visible and accessible to everyone, then why is the study of Nature a specialisation of only science?

COHERENCE PRINCIPLE
Competition

Figure A4.9-11: Incoherent link between informed NOS view and Knowable statement about Nature, relating to the theme *Find out and learn*

SUMMARY STATEMENT

Scientists research to find out the cause/purpose of things, yet there are some things for which we will never know the meaning (e.g., earthquakes and ocean tides in Nature). (Unknowable, Naturalistic) (Unknown) (Samuel)

NOS

They research stuff that has been discovered or investigate it…to find out what the cause or purpose of a thing…Because there‘s no point of living in a world that we don‘t know. What‘s the point of living in it? Why are we living in this kind of world? So you want to find out stuff so that we can identify what we‘re actually doing here.

The questions ―What is the cause?" and ―What is the purpose/meaning?" ask very different things and tap into different knowledge domains (i.e., science and religion, respectively). What kinds of questions can science answer?

NATURE

Nature is a mixture of different things which changes all the time, like…the tide in the ocean… It can be complicated how everything works and we‘ll never be able to find out the meaning for, like why does the tide in the ocean actually go like that, why is it bigger, high tide is here, low tide is there or whatever…It is quite confusing to figure out when something‘s going to happen, or why it happens. Like, who‘s causing it. Anything can happen at any time, like tornadoes or earthquakes

I don‘t see a purpose to earthquakes, because it‘s like the bottom of the earth is like this (two plates leaning up against each other) (and it just gave in…) so that‘s an earthquake that people just fall in.

COHERENCE PRINCIPLE

Competition

Figure A4.9-12: Incoherent link between informed NOS view and Unknowable and Naturalistic statements about Nature, relating to the theme *Unknown*

SUMMARY STATEMENT

Reza doesn‘t seem to distinguish between that which scientists study, and God‘s control of future events: On the one hand, scientists search and investigate so that they can tell us the correct information about it, and they tell us only tell us only when they know everything. However, Nature is controlled by God (e.g., floods, ice breaking, repairing a mountain, world ending) and only God knows what will happen (e.g., person dying). (Science vs. religion) (Reza)

NOS

[Scientists sometimes disagree] Because they are not very sure…They don‘t know everything…One searches a bit and another searches the whole way. The one who searches a bit might be wrong. The one who searches the whole way is right…Sometimes half a way they search so they don‘t know everything. They won‘t tell until they know everything. They will eventually find out everything so they can tell people.

What is the domain of scientific knowledge and ideas and what belongs in the domain of religious beliefs?

NATURE

Without God things can‘t happen in Nature. He can take the flood away or if God wants Nature destroyed it can be destroyed.
If God wants, the ice will break, but sometimes if God doesn‘t want, the ice will stay like that…God controls everything Without God things can‘t happen in Nature. He can take the flood away or if God wants Nature destroyed it can be destroyed.
In Nature, if you damage the mountain it can‘t be repaired until God wants it to be repaired. We can protect Nature by not littering, but otherwise only Allah can protect Nature.
Shaitun and ghosts like that, also *Eblise*…One day they‘re going to come and blow a trumpet and the whole world‘s going to die, melt in the hot steam. The world will stop and that will be the end. But it‘s not going to be now, it‘s still a lot more years. We won‘t be alive still.

COHERENCE PRINCIPLE

Competition

Figure A4.9-13: Incoherent link between informed NOS view and Unknowable and Super-naturalistic statements about Nature, relating to the theme *Science vs. religion*

SUMMARY STATEMENT

Scientists study mountains and explain things about them based on facts, yet there is some uncertainty regarding how mountains are started—perhaps they were created by God. (Science vs. religion) (Samuel)

NOS

…They can look at rocks or mountains and work out stuff…

They have to work with facts that have proven to be true. If they use their creativity the facts will not be true and their investigation will be made up.

Which knowledge framework should we turn to in trying to understand things in the natural world?

NATURE

No religion thinks that Nature created itself or anything like that. Someone has to put a mountain there, and then the mountain turns to sand, and every single year the mountain gets bigger, and eventually two mountains hit and millions of sand just comes down and goes into the ocean…I don‘t know._Just someone had to make it…to start with. I think God created it…

Nature is fascinating how we don‘t have to make it beautiful. It‘s already beautiful for us. But how did it get that beautiful and who made it so beautiful?

COHERENCE PRINCIPLE

Contradiction

Figure A4.9-14: Incoherent link between informed NOS view and Super-naturalistic and Positive statements about Nature, relating to the theme *Science vs. religion*

SUMMARY STATEMENT

Scientists‘ figure out the details by looking closely (e.g., minerals that make up the world), however, this clashes with religious people‘s theories and I think God created the world. (14) (super naturalistic, naturalistic) (Science vs. religion) (Shanon)

NOS

Scientists look closer (analyse) the item/term and figure out clues that‘ll give answers, then go deeper to figure out details.

NATURE

The world was built up by lots of different minerals forming together…but I think God must have created the world—science and religion clash.

How to make sense of scientific knowledge when it conflicts with personal religious beliefs?

COHERENCE PRINCIPLE

Contradiction

Figure A4.9-15: Incoherent link between informed NOS view and Naturalistic and Super-naturalistic statement about Nature, relating to the theme *Science vs. religion*

3. THEORY-LADEN, SUBJECTIVE:

3.1. Coherent links with naive NOS views

SUMMARY STATEMENT

In real science, scientists think about what will happen, and in Nature we know/can generally predict what will happen. (Predicting Nature) (Brian)

NOS

Maybe that's what they think, or like, maybe…if they think there's not gonna be global warming they just think that the sun will just miss Earth or something. [So it's just their ideas/their own thoughts…That's [not] real science.]…Because they're just using their imag-…'cos they're not actually thinking what *will* happen. Or what, or that's what they think but they don't actually check that…

What do we do with scientific predictions and forecasts?
To what extent is Nature predictable?

NATURE

There's nothing not to understand about Nature. We already know what is going on and what will happen. For example, we can say what the weather will be like from the satellites.

Nature is predictable…

[Re: Nature just does anything that could happen, like thunder can just hit the tree and the tree can fall and cause fire, but it's still predictable.] Well, we can know…that there's gonna be lightning or thunder but we don't know where it's going to strike. [Or you could predict there'd be heavy rain, you don't know how much rain] or where there *will* be (follow up). *(i.e., We can predict general events, but not the specific details of those events.)*

COHERENCE PRINCIPLE
Symmetry

Figure A4.9-16: Coherent link between a naive NOS view and Knowable statements about Nature, relating to the theme *Predicting Nature*

SUMMARY STATEMENT

Scientists don't know everything, e.g., why these flowers prick us—and then we get sick from them. (Unknown) (Reza)

NOS

…*Scientists* don't know everything...…One searches a bit and another searches the whole way. The one who searches a bit might be wrong. The one who searches the whole way is right…Sometimes half a way they search so they don't know everything. They won't tell until they know everything. They will eventually find out everything so they can tell people... They won't put extra things in there…Not [things that they have] thought, they have to look.

NATURE

…We can't understand why those flowers prick us…we can't touch them because we're going to get sick from those flowers.

How can scientists tell us things if they only know part of it? (Perhaps partial knowledge is better than no knowledge?) There are some things we do not/cannot know about Nature.

COHERENCE PRINCIPLE
Explanation

Figure A4.9-17: Coherent link between naive NOS view and Negative statement about Nature, relating to the theme *Unknown*

SUMMARY STATEMENT

You need proof, and there's lots of evidence about dinosaurs (e.g., bones) and proof of other worlds/planets. (Evidence) (Raashid)

NOS	NATURE
…You can't just take guesses and use your imagination. You need proof. e.g. what people looked like. e.g., not when they do investigations. They can tell by the structure of [dinosaurs'] bones how they looked like and they can tell what they ate by looking at the size and shape of their teeth. e.g. Molars, incisors, canines, etc. and sharpness. e.g., carnivores had long canines.	[Nature] changes when stuff are extinct, like dinosaurs used to play a part in Nature, but now they're extinct…There's lots of evidence that dinosaurs did exist, bones and all…Archaeologists dig up bones and they can see what links up. They more or less know the bones, like what the rib cage and the spine looks like…

What about natural phenomena for which there isn't enough evidence?
Do we only rely on knowledge for which there is evidence? (What about theoretical propositions, inferences, etc?)

COHERENCE PRINCIPLE
Symmetry

Figure A4.9-18: Coherent link between naive NOS view and Knowable statement about Nature, relating to the theme *Evidence*

SUMMARY STATEMENT

We need to find facts about Nature. (Find out & Learn) (Maya)

NOS	NATURE
[Science is only based on facts] because you have to find facts about what you are studying and then you can look even further.	We need to discover things and find facts about Nature because it's such a nice part of life that I think people should know more about it. It is possible to find out things about Nature…

What do we do with (how do we make sense of) the parts of science that are not based on facts?

COHERENCE PRINCIPLE
Symmetry

Figure A4.9-19: Coherent link between naive NOS view and Knowable statement about Nature, relating to the theme *Find out and learn*

SUMMARY STATEMENT

We find out things from experiencing it ourselves. (Search, explore, observe) (Dyllan)

NOS

…Voyager 1 that was sent out so they can experience our solar system, Mr. [B] says it‘s only gone passed Pluto now…And that it‘s shut down because it works off solar power and now it‘s not getting any sun because it‘s past Pluto. So, maybe, maybe it‘s not past Pluto. I don‘t know…It‘s strange. Or maybe…as they passed Pluto another sun came so it was still on…

NATURE

We can find out things about Nature from the Internet, and books, and we can experience it ourselves, like by going to the jungle or somewhere. Or maybe people experienced a volcano erupting…

To what extent can/should we trust the empirical data upon which scientists base their knowledge?
How do we make sense of the notion that scientists can sometimes make mistakes; that scientific knowledge is regarded as empirically-based and reliable, yet there is also a human component in the development of scientific knowledge?

COHERENCE PRINCIPLE
Explanation

Figure A4.9-20: Coherent link between naive NOS view and Knowable and Super-naturalistic statement about Nature, relating to the theme *Search, explore, observe*

SUMMARY STATEMENT

Scientists are wrong therefore I don‘t trust them; I‘d rather believe God. (Science vs. religion) (Dyllan)

NOS

Scientists say that the space comes to an end. I really don‘t believe. I think it goes on forever.

Say the Voyager 1 passed Pluto and now it‘s shut down, its not getting any sunlight and now it‘s travelling for a long time and there‘s a planet that looks similar to Pluto or maybe has the same structure as Pluto and now they get sunlight again and they say, ―Ah, it it‘s just past Pluto, and it receives light from somewhere else.” But it‘s not Pluto. It‘s like a different planet…

NATURE

Our teacher says in science that scientists say the sun is going to blow up or it is going to fall into itself, or the Earth is going through the same thing, but in one billion years. That‘s quite a long time. But I don‘t trust what they tell us, because when I go to church, they sing a hymn where the last line says, ―world without end” and it goes ―Amen”. So I think if God says there will be no end, I think that‘s right. I don‘t believe the scientists. They are not super-humans. They also make mistakes, so maybe they‘re wrong about the world ending.

If scientists sometimes make mistakes, and what they say conflicts with personal religious beliefs, how should we regard scientific knowledge (e.g., disregard it in favour of religious beliefs)?

COHERENCE PRINCIPLE
Symmetry

Figure A4.9-21: Coherent link between naive NOS view and Super-naturalistic statement about Nature, relating to the theme *Science vs. religion*

3.2. Incoherent links with informed NOS views

SUMMARY STATEMENT

Archaeologists found fossils, but no-one lived in that time so I don't know how scientists knew about dinosaurs. (Uncertain, doubt, mistakes) (Dyllan)

NOS

I have heard people say that there was no food so the dinosaurs died. And I heard a volcano killed the dinosaurs. But no-one was alive then so it was difficult to give a right answer.

It is very difficult to say how scientists know how dinosaurs look like because they weren't there.

NATURE

We can find out things about Nature from…we can experience it ourselves…or they are an archaeologist that found fossils.

How can we know about things that we were not alive to observe/experience first-hand?
How much can we know the history of the natural world?

COHERENCE PRINCIPLE
Contradiction

Figure A4.9-22: Incoherent link between informed NOS view and Knowable statement about Nature, relating to the theme *Uncertainty, doubt and mistakes*

SUMMARY STATEMENT

Scientists help everyone to understand the world better, yet it is unnecessary to learn more about Nature (Find out & Learn) (Victoria)

NOS

[Scientists do their work] to help everyone understand the world better...Most of the time, their own opinions are [involved]…because you have to add your opinions to make more sense of it, otherwise it will just be a whole lot of facts…That's why they're sometimes a little bit unsure, because…scientists have their own opinions, their different opinions. That's why they're a little unsure, ja.

NATURE

…But we don't really need to study Nature or to learn more about it, otherwise it might just take away the lust to be in Nature. It's nice to have some mysteries unsolved just to keep it fascinating. Nature is mysterious, like how does the ice stay ice even though the sun comes down on it?...It is mysterious even though we are used to it.

What is the role/purpose of science? Why/do we need to know more about the natural world?

COHERENCE PRINCIPLE
Contradiction

Figure A4.9-23: Incoherent link between informed NOS view and Unknowable and Positive statement about Nature, relating to the theme *Find out and learn*

4. SOCIALLY- AND CULTURALLY-EMBEDDED:

4.1. Coherent links with naive NOS views

SUMMARY STATEMENT

Nature is complicated but it can be understood eventually. (Find out & learn) (Aamir)

NOS

A reason that scientists might disagree is that one scientist will have different facts but eventually they‘re both right because they don‘t understand what the thing means then much later they figure out it‘s actually the same.

NATURE

Nature can be complicated because of all the different things in the world, like something will grow here but it won‘t grow somewhere else. But if you put your mind to it you can understand it.

Can we know and understand everything in the natural world?
Can there be multiple possible valid answers in science?

COHERENCE PRINCIPLE
Explanation

Figure A4.9-24: Coherent link between naive NOS view and Knowable statement about Nature, relating to the theme *Find out and learn*

SUMMARY STATEMENT

Nature is sometimes unexplained and unpredictable, and scientists are sometimes unsure if their answers are correct. (Uncertain, doubt, mistakes) (Yamina)

NOS

Sometimes they are not sure if their answers are correct.

How do we make sense of the notion that some scientific knowledge is uncertain, when we need to trust science and base important things (e.g., new developments) on scientific knowledge?
How much of Nature can we know – which is more powerful, science or Nature? (Is science powerful enough to know everything about Nature, or is Nature more powerful in that there will always be more that remains unknown?)

NATURE

…Storms are things we can‘t find out about in Nature. And we can‘t predict when it will rain. Sometimes it just starts raining without us knowing. And if the volcano has been sleeping for a long time and it suddenly erupts, that isn‘t ordinary.

…We see a lot of things, but there is more to Nature as well, like, there‘s other creatures in Nature that we haven‘t seen before.

COHERENCE PRINCIPLE
Explanation

Figure A4.9-25: Coherent link between naive NOS view and Unknowable statement about Nature, relating to the theme *Uncertainty, doubt, mistakes*

SUMMARY STATEMENT

There are some things in Nature that can‘t be explained, and scientists disagree if they don‘t have enough facts. (Unknown) (Dyllan)

NOS

[Scientists sometimes disagree because] they don‘t have enough facts.

What do scientists do about the natural phenomena that cannot be understood and/or explained?

NATURE

…Sometimes I wonder, with my dog, he just does this weird stuff and there‘s no real answer. Sometimes he just digs holes in the ground even if he has no bone. I don‘t understand that. And he‘s got an ear problem, so we keep cleaning out his ear and we take him to the doctor and then his ear is fine again, but afterwards his ear is funny again. It goes on like that forever, so it‘s confusing to me. There is some stuff in Nature that we can‘t give an explanation for.

Nature is complicated. Volcanoes just erupt. Why do they erupt, if for five years it stays the same and then it just blows up all of a sudden? Why do hurricanes start? How do they start? Why do fires happen and just grow and grow, and cause havoc?

COHERENCE PRINCIPLE

Explanation

Figure A4.9-26: Coherent link between naive NOS view and Unknowable statement about Nature, relating to the theme *Unknown*

SUMMARY STATEMENT

Nature is complicated, so scientists need to work hard searching everywhere/everything in order to tell the truth— they can‘t just search halfway and then add their own thoughts. (Search, explore, observe) (Reza)

NOS

[Scientists sometimes disagree] because they are not very sure. They don‘t know everything…One searches a bit and another searches the whole way. The one who searches a bit might be wrong. The one who searches the whole way is right. They don‘t see who‘s telling the truth when the true person wants to tell him, ―*I'm* talking the truth!" Because one is telling lies, saying, ―I searched more." But the other one who searched properly, he‘s talking the truth.

What is the relationship between the results of scientists‘ searches for evidence, and things they can put in from their minds?

NATURE

It is complicated because in the whole world there‘s a lot of things that is Nature. If you‘re very interested you can search about it. But it will take a very long time to understand it. And we can‘t put things from our minds into it. You can‘t just get it now, just go and write all it down…you go to search and there you see it.

You have to do a hard job [of searching], you have to go walk, to have to work like a donkey!

COHERENCE PRINCIPLE

Symmetry

Figure A4.9-27: Coherent link between naive NOS view and Unknowable statement about Nature, relating to the theme *Search, explore, observe*

SUMMARY STATEMENT

Scientists find out more about animals (e.g., insects, creatures, butterfly life cycles) by research/observation. (Search, explore, observe) (Yamina)

NOS

They find out more about the animal then they'll be sure about it. To find out more they go to archaeologists. Then they'll no longer disagree….

What are the causes of disagreements amongst scientists? And how are disagreements resolved?

NATURE

There's wildlife, like animals, and there's plants and insects. Go to different places and you'll find <u>different</u> stuff…To find out things we get research. Anybody just sees and finds out…Nature is orderly and things in Nature grow in cycles, like the cycle of how flowers bloom. And, for example, the butterfly cycle…we can find everything in front of us and we can see and touch. The more you see plants and creatures of Nature the more you'll understand...

COHERENCE PRINCIPLE

Symmetry

Figure A4.9-28: Coherent link between naive NOS view and Knowable statement about Nature, relating to the theme *Search, explore, observe*

5. IMAGINATION AND CREATIVITY:

5.1. Coherent links with naive NOS views

SUMMARY STATEMENT

Nature should be studied to pass on knowledge to future generations, and when scientists' minds run wild it is because they are remembering things that were learnt previously (e.g., recalling the names of different things, such as plants, which have been memorised. (Legacy of knowledge) (Aamir)

NOS

When their minds run wild they are remembering things that were learnt before…Sometimes they might have learnt that a long time already, but then they might learn it again but then they don't remember the things that they learnt. So they might remember a few stuff so…then it will carry on.

Why do we need to develop knowledge about the natural world? (e.g., remembering and passing on knowledge to the next generation)

NATURE

The natural environment should be studied to pass on the legacy when people die (e.g., plant names).

It is hard to memorise all the names of different things around you, but if you put your mind to it you can…It's just a question of working hard enough.

COHERENCE PRINCIPLE

Explanation

Figure A4.9-29: Coherent link between naive NOS view and Knowable statement about Nature, relating to the theme *Legacy of knowledge*

SUMMARY STATEMENT

We will always be learning more about Nature, but scientists (e.g., zoologists, botanists, biologists, environmentalists) do not use their imaginations because then their ―scientific facts” would be rubbish. (Unknown) (Shanon)

NOS

I hope [scientists don‘t use their imaginations/creativity], because then every ―scientific” fact will be rubbish. Scientists need to find the truth, not the imagination in their heads… It‘s not okay if they‘re trying to prove something.

What is ―truth”?
In what way/s can imagination/creativity play a role in developing proof in science?

NATURE

We can always learn more things about Nature. Different people do that, like zoologists, botanists, biologists, and environmentalists. Nature is interesting, because we don‘t really understand properly, we‘re still at a point where we are learning more about it. And it will always probably be like that.

COHERENCE PRINCIPLE
Symmetry

Figure A4.9-30: Coherent link between naive NOS view and partly Knowable and partly Unknowable statement about Nature, relating to the theme *Unknown*

SUMMARY STATEMENT

Scientists need proof about Nature, and to learn about it you can go to the place, dig up things, or read books and watch television (TV). (Search, explore, observe) (Raashid)

NOS

…You can‘t just take guesses and use your imagination. You need proof. e.g. what people looked like. e.g., not when they do investigations.

What is ―proof”?
Can the existence of super-natural phenomena be proven?

NATURE

If you are very fascinated about [Nature] and you want to find out, then definitely go ahead and learn…But to learn about Nature you don‘t have to go to a certain place and go study about it…you can read books and watch TV documentaries (e.g., Discovery)….Maybe we can dig up our history.
We have proof there are other worlds, other planets. And super natural stuff…

COHERENCE PRINCIPLE
Explanation

Figure A4.9-31: Coherent link between naive NOS view and Knowable and Super-naturalistic statement about Nature, relating to the theme *Search, explore, observe*

SUMMARY STATEMENT

Scientists study Nature so they can know and tell us about it—what they present to people is the facts, not their own thoughts. (Find out & learn) (Reza)

NOS

They get the facts…which they then present [creatively] to people.

When they present…they won‘t put extra in there. It‘s not what they *thought*, they have to look. They can‘t just…because…you can see some scientists go up, then they say, ―No that‘s lie, they talking lies about it.” They must show the people. They can‘t just say, ―Ja, I found it.”

NATURE

…We can‘t put things from our minds into it. You can‘t just get it now, just go and write all it down…you go to search and there you see it.

Nature must be studied, because if we don‘t know we can‘t talk about it…

How does the use of imagination and creativity work together with the need for scientific knowledge to be empirically-based?

COHERENCE PRINCIPLE

Symmetry

Figure A4.9-32: Coherent link between naive NOS view and Knowable statements about Nature, relating to the theme *Find out and learn*

SUMMARY STATEMENT

Because of global warming, we need to find a new planet so we should study Nature to learn/know more—if scientists used their imagination it would be fiction. (Facts & truth) (Brian)

NOS

Because when you use your imagination it is fiction.

…What [are] their stories…based on?]…Maybe that‘s what they think, or …maybe…if they think there‘s not gonna be global warming they just think that the sun will just miss Earth or something. [So it‘s just their ideas/their own thoughts… That‘s [not] real science.]…Because they‘re just using their imag…‘cos they‘re not actually thinking what *will* happen. Or…that‘s what they think but they don‘t actually check that…maybe with a telescope… (i.e., real scientists don‘t use their imaginations).

NATURE

…We would need to find a new planet to live on, so I think we should study Nature and learn more and know more.

How are forecasts/predictions made in science?
What role does scientists‘ thoughts and imagination play vis-à-vis empirical studies?

COHERENCE PRINCIPLE

Explanation

Figure A4.9-33: Coherent link between naive NOS view and Conservationist statement about Nature, relating to the theme *Facts and truth*

SUMMARY STATEMENT

Scientists study Nature (e.g., satellite data, seeing things, technology) and they test/prove things. Scientists don't use their imaginations because then what they tell us about Nature would be fiction. (Facts & truth) (Brian)

NOS

Because when you use your imagination it is fiction.

…What [are] their stories…based on?]…Maybe that's what they think, or …maybe…if they think there's not gonna be global warming they just think that the sun will just miss Earth or something. [So it's just their ideas/their own thoughts… That's [not] real science.]…Because they're just using their imag…'cos they're not actually thinking what *will* happen. Or…that's what they think but they don't actually check that…maybe with a telescope… (i.e., real scientists don't use their imaginations).

What does it mean to use your imagination in science? How is this different to fiction?

NATURE

…We can say what the weather will be like from the satellites….We see so much of one thing that we already know so much about it…Scientists have discovered Nature and studied it and they've been telling us, so that's how we know things, although I don't know exactly how they find out things. They do have technology, like to find out how big a dinosaur was, they just put it in some scanner and that says how old….they always try to prove people wrong….

Besides for meat to eat, we can use animals as experiments like if someone has a serious illness and we can't stop it, then we try to find a cure and we have a whole of cures. Then we put that disease onto an animal and test and see if the animal is alright.

…I think we should study Nature and learn more and know more.

COHERENCE PRINCIPLE

Explanation

Figure A4.9-34: Coherent link between naive NOS view and Knowable statements about Nature, relating to the theme *Facts and truth*

SUMMARY STATEMENT

Scientists work with the facts concerning things that are there—visible and tangible parts of Nature. (Search, explore, observe) (Samuel)

NOS

They have to work with facts that have proven to be true. If they use their creativity the facts will not be true and their investigation will be made up.

How can we know about natural phenomena that are not visible and/or tangible?

NATURE

…in a laboratory, we create a laboratory to work out the DNA from people, etc.

I am very interested in the ocean and how these zillions of animals that we don't know about that live a million feet below us are living. If you have a modified submarine that can take pictures of it, then scientists can investigate where their mouth is and how they eat.
Nature is just there, like we can go there once or twice and just watch animals, or plants, or desert areas, or whatever. We know it's there, because we can touch the flowers and the rain, plants and animals… We can go anytime to a beach and there'll be Nature there… *(i.e., visible and tangible).*

COHERENCE PRINCIPLE

Explanation

Figure A4.9-35: Coherent link between naive NOS view and Knowable, Naturalistic and Neutral statements about Nature, relating to the theme *Search, explore, observe*

5.2. Incoherent links with informed NOS views

SUMMARY STATEMENT

Archaeologists found fossils, but no-one lived in that time so I don‘t know how scientists knew about dinosaurs. (Uncertain, doubt, mistakes) (Dyllan)

NOS

Archaeologists found bones, fossils, fossils of the dinosaurs, but obviously the skin has been eaten up by—and then, all they find is the bone, and they brush it and that, and all they see is the bone. But what if they are fooling us by just putting on skins but with the shape of the dinosaur‘s body and then they find another one and just put, just make his skin colour green. But if you go back in time it‘s red…?

NATURE

We can find out things about Nature from…we can experience it ourselves…or they are an archaeologist that found fossils.

In what way/s can imagination and creativity work together with empirical evidence in science? How can the role of imagination/creativity in science be distinguished from trickery?

COHERENCE PRINCIPLE
Contradiction

Figure A4.9-36: Incoherent link between informed NOS view and Knowable statement about Nature, relating to the theme *Uncertain, doubt, mistakes*

SUMMARY STATEMENT

Scientists like to explore, although Nature lacks variation (e.g., similar tree species. (Search, explore, observe) (Aamir)

NOS

They like to invent things and they like to explore.

NATURE

It is boring because you see almost the same thing every day, like the tree there by my house. Most of the trees and things look the same.

How do we make sense of diversity in nature whilst experiencing familiar phenomenon and identifying commonalities amongst species?

COHERENCE PRINCIPLE
Competition

Figure A4.9-37: Incoherent link between informed NOS view and Negative statement about Nature, relating to the theme *Search, explore, observe*

Appendix 5.1
FEEDBACK FROM STUDENTS REGARDING THEIR WORLDVIEW INTERVIEWS

Students found it very enjoyable and interesting to discuss their views of the natural world. They also felt that being engaged in discussions about Nature had helped them to know more about the topic:

> “Fun and interesting. It helped me more to think about Nature, and I think I learnt something today.” (Shafia, worldview interview)
>
> “….the questions were interesting, I learnt a lot…” (Dan, follow-up interview)
>
> “How did I find this…Oh, it‘s very interesting. I learnt more about, maybe I‘ll do better in my work.” (He smiles.) (FA, worldview interview)
>
> “It was nice to talk about…to tell Miss and all the things what we know, to tell Miss is nice then we can share something with the other people, you can tell the person, like, more things about you…like if Miss tells you some things I get more knowledge, if I tell Miss then Miss gets more knowledge. It‘s all like about knowledge to get knowledge from each other‘s talk…if you talk to this person and that person, if you will know some things and you will know some things, if you tell each other, like, now things you will know more, but never less, you will know more, but never less, so it is better to ask, and, like, know more things about a person” (Reza).

For some students, the worldview interview provided a unique opportunity for them to think about the natural world in an explicit, focused and comprehensive way:

> “…. Yoh,[48] I think [thought] so hard and I‘m so proud of myself.” [Smiling] (ND, worldview interview)

Furthermore, in reflecting upon and responding to their worldview narratives, some students became aware of how much they knew about the natural world, which proved to be a most affirming realization for them:

> [I found this]…Interesting… And I‘ve figured out…I thought about Nature more than I‘ve ever…! (He laughs) (DH, worldview interview)
>
> Did I actually say this? (He smiles.)…Because I never knew I could make up a story like this… I remember [saying] everything…I like the story. It‘s very good. […] (FA, follow-up interview)
>
> “…. I can‘t believe that I said that stuff (She smiles/laughs.)…I just can‘t believe it. (Smiling.)… Because I, like, never said that stuff before and it, like, just came out of me when I was speaking to you…” [Later, again, at the end of the interview]: “I just can‘t believe what I did there! [She laughs/smiles, pointing to her Nature story.] (NS, follow-up interview)

[48] An expression of amazement

Appendix 5.2
SUMMARY OF IMPLICATIONS AND RECOMMENDATIONS ARISING FROM THE RESULTS OF THE PRESENT STUDY

The findings reported in the present study hold implications for science education researchers and science teachers, regarding students‘ views of the natural world, their views of NOS, and coherence of these two domains.

Science education researchers

In light of the complexity of the concept of Nature, and the diversity of views described by students belonging to a particular religious group (Chapter 4, page 149; Chapter 5, pages 235 and 240), worldview researchers are advised:

- To aim to elicit detailed and nuanced descriptions from respondents when studying their views about Nature (Chapter 5, page 240);
- To refine the use of continua that reflect the subtle distinctions and relative strengths of individuals‘ views, in analysing, describing and comparing various individuals views of the natural world, (Chapter 5, page 233 and page 240).

Regarding the collection and analysis of NOS data, science education researchers are advised:

- To create an immediate review opportunity with respondents after administering written questionnaires (before conducting initial analyses of the data and then conducting final follow-up interviews) (Chapter 5, page 222);
- To ask students to explicate the meanings of some of the terms they use in describing their NOS views (e.g., references to myths, theories, opinions, imagination and creativity in science) and to illustrate their explanations with examples (Chapter 5, page 219);
- To consider together, all of the statements relating to a particular NOS aspect (e.g., tentativeness), when assessing an individual‘s level of understanding pertaining to that aspect of NOS (Chapter 5, page 223);
- To present the NOS data for each case in the form of an individual NOS profile, when analyzing, in-depth, the results of multiple cases (Chapter 5, page 221).

In light of the lack of established methodology for analysing the little-known relationship between students‘ worldviews and their NOS views (Chapter 2, page 49), science education researchers are advised:

- To continue to explore the use of various principles of explanatory coherence as a means of providing focus and structure to the analyses of such data (Chapter 5, page 263);

- To apply an additional explanatory coherence principle of system complexity, in analysing the coherence within a particular set of views (Chapter 5, page 263).

Science teachers

In light of the diversity of students' views of the natural world, and the inherent complexity of the concept of Nature (Chapter 4, page 160; Chapter 5, page 240), science teachers are advised:

- To draw upon differences in students' views to stimulate discussion and reflection (Chapter 5, page 234);
- To emphasise the inherent complexity of the concept of Nature (rather than adopting an implicit and piecemeal approach to teaching about the natural world) (Chapter 5, pages 239-240 and 256);
- In regard to epistemological descriptions of Nature, to emphasise that which is uncertain and unknown about Nature, and not merely to teach about what is already known (e.g., natural laws and patterns, etc.);
- In regard to ontological worldview descriptions, to encourage students to discuss and reflect upon their ideas, especially when there are apparent conflicts between students' personal beliefs and science;
- To elicit students' particular conceptions about Nature and discuss these specifically (rather than trying to relate generalised elements of students' views with a limited perspective of what might be considered a scientifically-inclined view of the natural world) (Chapter 5, page 243).

In order to address students' limited and incoherent understandings of the kinds of work that scientists do, the aim/purpose of science, and the impact of science (Chapter 4, pages 104, 106 and 129; Chapter 5, page 213), science teachers are advised:

- To provide students with detailed insights into the ways in which scientists work, including discussions about the diverse fields of science (e.g., the kind of subject matter studied in each field), and alert students to differences that exist amongst individual scientists (Chapter 5, page 217 and page 220);
- To also highlight the features of scientific knowledge that are common to all fields of science (e.g., that it is empirically-based, theory-laden, and so forth), and draw attention to how the various aspects of NOS (e.g., the use of imagination and creativity) would be applied in each of the various fields of study (Chapter 5, page 217).

In order to improve students‘ alternative and/or limited understandings of particular terms used in the context of science (Chapter 4, page 115), teachers are advised:

- To clarify and explain what is meant by terms such as myth, theory, fact and opinion, and imagination and creativity (Chapter 5, page 219);
- To distinguish the meanings of these terms when used in the context of science as opposed to everyday language (Chapter 5, page 219).

In response to the themes that were identified amongst the students‘ NOS views about each NOS aspect (relating to informed, developing and naive levels of understanding), and the inherent complexity of NOS (Chapter 4, page 107; Chapter 5, page 226), science teachers are advised:

- To draw upon these various themes of NOS responses in order to address students‘ specific concepts or misconceptions when teaching them about NOS (e.g., views relating to mistrust/doubt in science) (Chapter 5, page 224 and page 228);
- To not underestimate the inherent complexities involved in students‘ developing informed understandings of NOS in all its various aspects (Chapter 5, page 228);
- To make explicit for students how the various aspects of NOS all work together (e.g., focus on the interplay between the empirically-based aspect of NOS and the credibility and reliability of scientific knowledge on the one hand, in relation to the tentative, theory-laden and subjective, socially- and culturally-embedded, and imaginative and creative aspects of NOS on the other) (Chapter 5, page 224 and page 228).

Overall, the relationship between students‘ views of the natural world and their views of NOS is a complex one. Students‘ views of Nature and their NOS views lack internal coherence, and there are incoherent links—and in some cases, explicit worldview conflicts—between the two sets of views (Chapter 4, pages 168, 187 and 199; Chapter 5, page 253). Consequently, science teachers are advised:

- To make the complex relationship between Nature and NOS explicit (Chapter 5, page 256);
- To provide opportunities for students to reflect upon and discuss the various coherence issues that arose in this study, regarding students‘ views of the natural world, their understandings about the nature of science, as well as the relationship between the two (Chapter 5, pages 228, 244 and 258);
- To provide opportunities, during group discussions, for students to become aware of their own views and to start to problematise them (Chapter 5, page 243);

- To help students to grasp how explanations from alternative frameworks can exist alongside one another in their conceptual frameworks, and to build bridges that connect science with other important aspects of their lives (Chapter 5, page 243);
- To address *specific* questions concerning the relationship between various scientific and religious presuppositions, beliefs, theories and practices (rather than discussing broadly the differences between particular worldviews) (Chapter 5, page 244).
- To teach students about the scientific worldview without expecting them necessarily to take the view to be their own (Chapter 5, page 243);
- To include discussions about presuppositions in science, and emphasise that science is a way (not *the only way*) of thinking about or making sense of natural events and phenomena (Chapter 5, page 243);
- To encourage students to interrogate scientists‘ beliefs and procedures, how conclusions are reached, and how decisions and choices made in science (Chapter 5, page 243).

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